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Plant Operation

EXPERIMENTAL LAUNDERING OF AIR DIFFUSER PLATES *

By L. R. Setter and G. P. Edwards

City of New York, Department of Public Works

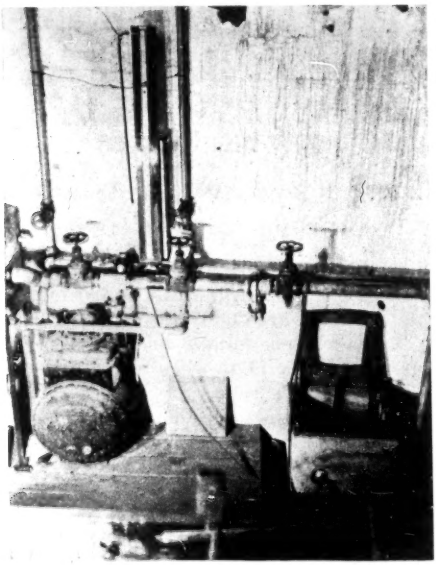
Air is supplied to the activated sludge at the Wards Island sewage treatment plant through alundum plates grouted into precast concrete boxes. These plates, which are one foot square, when new will pass 14 to 20 cubic feet of free air per minute under a pressure equivalent to *two* inches of water below the plate when tested dry at 70° F. This is known as the manufacturer's rating of permeability. The plates at Wards Island have gradually become clogged both from the top and bottom and for the desired air flow, high pressure losses are produced. A pressure of two or more pounds per square inch frequently causes the grouting to fail. One blown plate puts out of operation all of the 56 controlled by the same valve. Since the plates are more or less permanently fixed, it is necessary to clean them in place.

The Wards Island sewage treatment plant was put into operation in October, 1937. In less than two years it became necessary to clean some of the plates and the clogging has become worse year by year.

When the plates were laundered, the tank was emptied, the plates were hosed with water and scrubbed with a deck brush. Then about a half pint of caustic soda (25 per cent NaOH) was added to each plate with the air shut off. The caustic was allowed to react for 12 to 18 hours and the tank was put back into service without washing out the alkali. The benefits derived from this type of cleaning seemed to diminish after a few treatments. In 1943 the plates were clogged again within two or three months after cleaning.

In August, 1943, two concrete boxes (Plate 1) were constructed to determine the characteristics of plates at various stages of cleaning. Air measured in a dry test meter was permitted to pass up through the porous plate one inch thick on which a constant water level of two inches was maintained. A 40-inch water manometer for the measurement of the total applied pressure and a thermometer were connected directly to the underside of the plate. The humidity was measured gravimetrically or by allowing a stream of air to blow on a hygrometer. In making a test, the plate was fastened into place and air at a rate of 20 to 25 c.f.m. or at a pressure of about 37 inches of water was passed through the plate until equilibrium was established. This generally required 15

* Presented before the Water, Sewage, and Sanitation Division of the American Chemical Society in New York, 1944. Released for publication in *This Journal*.



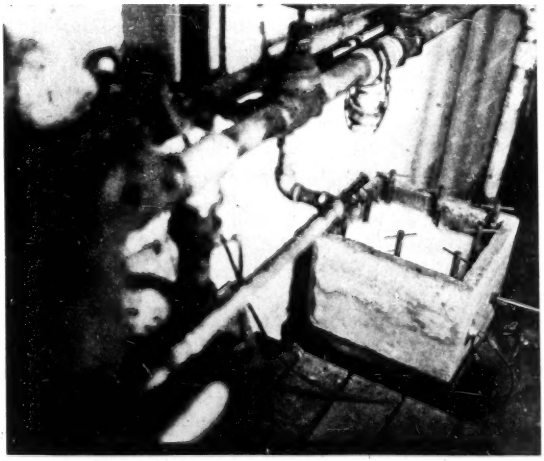


PLATE 1.—Diffuser plate testing equipment at Wards Island sewage treatment plant.

to 30 minutes. The air volume was then reduced in steps and the pressure and volume of air passing the 100 square inches of free plate surface were recorded and later calculated on the basis of one square foot.

Six unused plates purchased under the original contract were tested to obtain a standard for comparison. The data as presented in Table 1 show the permeability of the dry diffuser plates and their characteristics with air pressure under and a column of water over them. The loss of head through the plates for various air flows are shown in Columns 3 to 6. The rates of 1.1, 2.2, and 4.4 cubic feet of free air per minute per square foot of plate surface in Columns 3 to 6 respectively, represent at Wards Island air ratios of 0.3, 0.6 and 1.2 cubic feet per gallon of sewage at the design flow of 180 m.g.d. The loss of head recorded does not include the constant head of two inches of water. The average results indicate that in these unused plates 2.9, 3.28 and 3.6 inches of water pressure are lost for air flows of 1.1, 2.2 and 4.4 c.f.m., respectively.

TABLE 1. *Air Pressure Loss Through New Unused Diffuser Plates*

Plate No.	Permeability * (c.f.m. per sq. ft.)	** Pressure Loss Expressed in Inches of Water with an Air Flow of			
		1.1 c.f.m.	2.2 c.f.m.	4.4 c.f.m.	16.3 c.f.m.
(1)	(2)	(3)	(4)	(5)	(6)
A	18	2.6	2.8	3.2	6.8
B	14.7	2.6	3.15	3.4	7.1
C	15.9	2.95	3.3	3.9	7.8
D	18	2.9	3.15	3.4	7.1
E	14.7	3.2	3.5	3.8	6.0
F		3.1	3.3	3.8	7.7
Average	16.3	2.9	3.28	3.6	7.1

* Rate of air flow at observed temperature and humidity and an air pressure equivalent to two inches of water under air dry diffuser plates. The manufacturer's rating was guaranteed at from 14 to 20 permeability.

** The pressure loss is the total applied pressure below the plate less a column of air and water over the plate equivalent to two inches of water.

A comparison of the air flows through dry plates at a pressure of two inches of water with the air flows through plates with water over them as shown in Columns 3 to 6 indicate the effect of water on the permeability. At the average permeability of 16.3 c.f.m. per square foot of plate surface, absorption of water has decreased the permeability by increased loss of head through the plate from 2 to 7.1, or 5.1 inches of water. Since in practice the plates are always covered with water, it seemed advisable to make the tests with the surface of the plates wet instead of dry.

Preliminary tests indicated that the diffuser plates could not be satisfactorily cleaned by either chromic-sulfuric acid, sodium hydroxide or ignition alone. For example, Figure 1 shows a set of curves derived

from the progressive laundering of Plate No. 7 by scrubbing with soap powder, treatment with cleaning solution, treatment with caustic soda, and finally by blowing the dried plate with air. This plate was not badly clogged on the bottom and the progressive treatment did finally clean it.

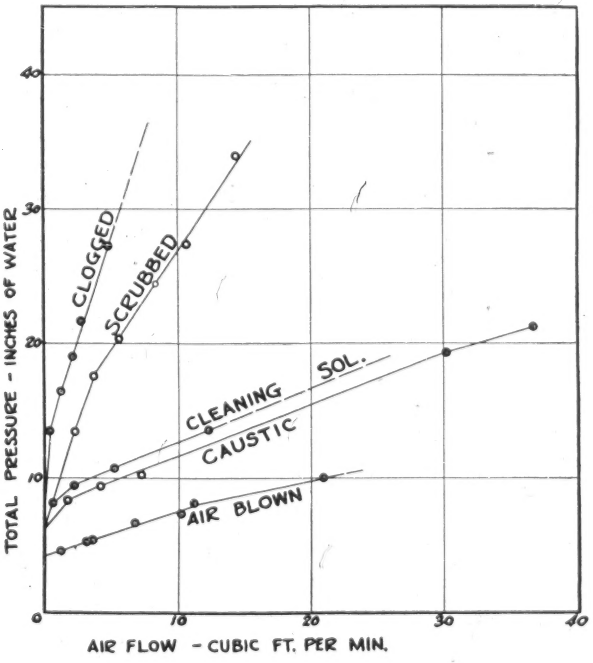


FIG. 1.—Diffuser characteristics for the progressive laundering of Plate No. 7.

The cubic feet of air passing one square foot of plate surface is plotted against the total pressure applied to the underside of the plate with a constant head of two inches of water above the plate.

1st. "Clogged."

2nd. "Scrubbed" with soap and water.

3rd. "Cleaning Sol."—Soaked in 5 per cent chromic acid in 80 per cent sulfuric acid for one hour, then rinsed thoroughly with water.

4th. "Caustic"—Overnight treatment with 150 ml. of 25 per cent caustic soda followed by a water pressure rinse.

5th. "Air Blown"—The dried plate was air blown at a pressure of 1.9 inches of mercury for 3.5 hours.

An attempt was then made to remove the caustic soda and the loosened clogging material from the plates which had been treated by brushing and with caustic soda—our usual plant method. After testing the permeability of ten used dry plates, each was treated with about 200 ml. of strong sodium hydroxide solution (25–50 per cent) and allowed to

TABLE 2.—*Effect of Laundering Dried Plates with Caustic, Water Pressure and High Velocity Air Through Pre-Dried Plates*

Plate No.	Air Press. Inches Hg	Blow Time Hrs.	Air Pressure Loss Through Plate Expressed in Inches of Water for an Air Flow of											
			1.1 c.f.m.			2.2 c.f.m.			4.4 c.f.m.			16.3 c.f.m.		
			Clogged	Caustic Treat.	Air Blow	Clogged	Caustic Treat.	Air Blow	Clogged	Caustic Treat.	Air Blow	Clogged	Caustic Treat.	Air Blow
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)	(14)	(15)
30	1	1	16	10.8	6.6	23	15	8.5	44.5	27	12			25.5
31	0.9	0.4	8.2	7.0	5.8	11.9	9.5	6.8	16	13.5	8.8	33	29	17.5
32	0.7	2.1	8.0	7.5	4.9	11.2	9.2	5.7	15	12.0	7.0	32	29	13.2
33	0.9	1.5	7.6	7.6	5.0	11.5	11.5	5.7	18	18	6.6	—	—	10.8
34	0.9	0.5	10.8	9.2	5.7	16.4	12.2	6.6	23.8	18	8.2	—	—	18
35	1.5	72.0	18.0	10.0	8.0	31.0	15.5	10.1	56.0	26.5	14.4	—	—	37.0
36	1.0	0.75	6.0	7.5	4.3	7.9	8.5	5.3	9.5	9.7	6.0	16	16	9.0
37	1.0	0.25	14.4	6.7	4.7	21.4	8.3	5.6	31.0	10.4	6.7		22.0	12.8
38	1.0	0.75	12.8	8.6	6.4	19.0	10.4	7.7	30.5	13.7	9.7		34.0	20.5
39	1.0	0.5	10.0	7.1	6.3	13.5	9.4	7.5	22.3	14.0	9.6	—	40.0	18.3
Average			11.2	8.2	5.8	16.7	11.0	7.0	26.7	16.3	8.9			18.2
New Plates					2.9			3.28			3.6			7.1

Note: Caustic treatment refers to adding 200 ml. of 25 per cent caustic soda solution to plates Nos. 30, 31, 36, 37, 38 and 39 for about five hours, except Nos. 36 and 37 which were treated for 16 hours; and 200 ml. of 50 per cent caustic soda for 16 hours to plates Nos. 32 to 35, inclusive. Following the caustic treatment each plate was flushed with water pressure before testing as shown in Columns 5, 8, 11 and 14, except Plates Nos. 33 and 36 which were flushed with water after the caustic test. The test after the air blow shown in Columns 6, 9, 12 and 15 was made after the pre-dried caustic treated and water washed plates were blown at a pressure and length of time given in Columns 2 and 3.

stand from 4.5 to 16 hours before they were washed from the top with water at hydrant pressure. When the plates had been retested, they were dried and air was blown through them at pressures of 0.5 to 1.5 pounds per square inch for 15 to 120 minutes to blow out any loose solid material. The effectiveness of each stage in the treatment is presented in Table 2, and the average results are shown in Figure 2. The high pressure water wash following the caustic soda treatment removed only 30 to 49 per cent of the loss of head from clogging. After blowing dry with air under a pressure of 0.5 to 1.5 p.s.i., from 63 to 79 per cent of the pressure loss was removed. The loss of head through the cleaned plates at an airflow of 4.4 c.f.m. varied from 6 to 12 inches of water and averaged 8.9 inches.

A loss of head through the plates of 6 to 12 inches of water is not excessive for normal volumes of air provided that a fair degree of uniformity in the laundered plates is obtained.

As the results obtained by blowing air through the plates after treatment with caustic soda and washing with water under pressure looked promising, the experiment was repeated using plates from a tank taken

out of service for cleaning in May, 1944. These plates had been scrubbed and blown dry with a relatively large volume of air before they were removed from the plate holder in the tank. Unlike the plates removed previously, the bottoms of these plates seemed to be coated with a layer of soot-like material. Plates Nos. 51 and 52 were tested and treated with 100 to 150 ml. caustic soda (25 per cent) for 18 hours. After retesting, air was blown through the plates and each was washed with about a gallon of water. They were then further washed from the top with about a quart of water under a pressure of 12 inches of mercury. After the plates were dry, air at 2 p.s.i. was blown through them

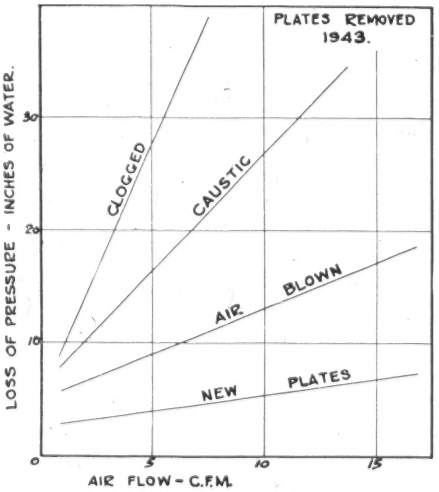


FIG. 2.—The caustic-water pressure-air blow method of laundering diffuser plates removed from aeration tank in 1943.

"Clogged"—Plates taken out of service prior to September, 1943.

"Caustic"—Treated with caustic soda and rinsed with water pressure.

"Air Blown"—Air dried, then blown with air at a pressure of one-half pound per square inch.

for 5 days. In spite of this very rigorous treatment, very little improvement was obtained.

At about the same time, two of the aeration tanks were emptied for cleaning and the plates were scrubbed and treated with caustic soda in the usual way. In one tank, the plates were rinsed by forcing water up through them and in the other by a hose from the top. Before putting the tanks back into service, the plates were dried and air at a pressure of about 1.5 p.s.i. was blown through them. Although the permeability was improved somewhat, the benefits were not commensurate with the material and labor expended.

It is likely that if the pressure water wash and air blow as a supplement to the regular brush and caustic soda treatment had been applied

before the plates had become so thoroughly clogged, the result of laundering in this way would have been satisfactory.

The fact that high scouring velocities are required to loosen and remove the material which causes the clogging, pointed to the use of a vacuum water wash. The vacuum water wash is the application of vacuum to the surface of the plate while sufficient water is added to keep the plate saturated. Vacuum at 12 to 22 inches of mercury means a suction equivalent to a pressure of 6 to 10 p.s.i. or 3 to 5 times greater than the maximum pressure permissible under the plate without blowing them out. The vacuum can be applied at the top of the plate without touching the grouting. The water acts as a carrier in the removal of the clogging material and permits less loss of the vacuum around the mouth of the nozzle applying the vacuum.

Accordingly, vacuum from a laboratory pump was applied to the top surface of the water saturated Plate No. 51 after it had been further treated with 10 ml. of 50 per cent sodium hydroxide. A considerable amount of fine sand and brownish black suspended and colloidal solids were removed; but when the plate was tested, very little improvement in permeability was observed. Then the underside of the plate was vacuum water washed. The wash water, which was coal black, contained much finely divided suspended material. A great improvement in the permeability was observed. Whereas 24 to 27 inches of water pressure were required for an air flow of 4.4 c.f.m. prior to the laundering of the underside, only 6.3 inches were needed after vacuum water washing of the bottom. New plates required a pressure of 3.6 inches of water for this air flow.

Plates Nos. 53 and 54 were now tested and vacuum washed without chemical treatment or air blowing of dried plates to obtain an analysis of the clogging material and its location within the plate. Plate No. 53 was vacuum washed first from the bottom and then from the top, whereas plate No. 54 was washed first from the top and then from the bottom. The results of laundering shown in Table 3 indicate that the clogging material lay on or in the underside of the diffuser. This is contrary to observation made on plates removed from aeration tanks in the fall of 1943 and indicates either that more impurities are passing the air filters or that the normal air impurities are not passing through the diffuser plate because of serious surface clogging.

Although a substantial weight of clogging material was removed by vacuum water washing from the top, even without a detergent, the tests indicate that the top vacuum water washing does not clean the plates sufficiently. Vacuum water washing from top and bottom is impractical, for plates fixed in place, even though most of the original permeability is restored by the treatment.

Previous experiments had shown the effectiveness of blowing air through the dried plates in removing the clogging material and the combination of vacuum water washing from the top and air blowing from the bottom was tried on six plates from an aeration tank out of service for cleaning. These plates had been scrubbed with a deck brush and

TABLE 3.—*Vacuum Treatment to Show Source of Pressure Head Losses*

	Pressure Loss Expressed in Inches of Water for an Air Flow of											
	1.1 c.f.m.			2.2 c.f.m.			4.4 c.f.m.			16.3 c.f.m.		
Plate Nos.	53	54	57*	53	54	57	53	54	57	53	54	57
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)	(12)	(13)
Clogged plate	17.0	19.0	26.0	28.0	30.0	40.0	—	—	—	—	—	—
Vac-washed bottom surface only	8.8			9.5			10.8			16.8		
Vac-washed top surface only		16.8			30.0							
Vac-washed both surfaces	8.2	8.6	8.1	9.1	9.5	9.0	9.6	11.5	9.5	13.2	23.0	13.3
New plates		2.9			3.3			3.6			7.1	

Note: See Table 5 for the volume of wash water and the quantity of clogging material removed in each step of the vacuum treatment.

* Plate No. 57 was vacuum water washed on both sides after having been treated with caustic for 18 hours, whereas Plates 53 and 54 were vacuum water washed without any pretreatment with chemicals.

TABLE 4.—*Effect of Vacuum Water Treatment of the Top Surface Followed by Air Blowing* *

Plate No.	Air Pressure Inches Hg	Blow Time Hours	Pressure Loss Expressed in Inches of Water for an Air Flow of							
			1.1 c.f.m.		2.2 c.f.m.		4.4 c.f.m.		16.3 c.f.m.	
			Before	After	Before	After	Before	After	Before	After
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)	(10)	(11)
58	1.0	17	14.0	7.1	22.5	8.2	39.0	10.0	—	23.5
59	2.2	18	7.5	6.0	11.8	7.1	19.2	8.9	—	23.0
60	1.7	5	8.2	5.3	11.5	6.0	18.0	7.4	—	14.8
61	2.0	5.5	7.2	5.0	8.5	5.7	11.1	7.0	—	15.5
62	2.0	18.5	12.0	8.0	20.0	10.8	40.0	18.0	—	—
63	2.2	18.5	9.0	6.8	12.2	9.9	23.0	12.8	—	44.0
Average			9.7	6.4	16.1	8.0	25.0	10.7	—	25
Average of New Plates			2.9		3.28		3.6		7.1	

* These plates were removed from a box in Tank No. 1 after the plates were deck brushed, treated with caustic overnight, rinsed with water, dried with air, and partially blown at a high air velocity. Prior to the testing shown in Columns 4, 6, 8, and 10, the individual plates were reblown at 1.0 to 2.5 p.s.i. for one to 18 hours. The plates were vacuum water washed, dried and blown at high air velocity at a pressure and length of time as shown in Columns 2 and 3 respectively. The plates were then tested as shown in Columns 5, 7, 9 and 11.

The characteristics of the plates in Tank No. 1 before "cleaning" were a loss of pressure head through the plates of 22.2 and 58 inches of water for air flows of 1.1 and 2.2 cubic feet per minute per plate, respectively; and after caustic treatment and air blowing the dry plates the pressure loss was 21, 32 and 59 inches of water for air flows of 1.1, 2.2 and 4.4 cubic feet per minute, respectively.

Air temperature 74 to 76° F., relative humidity 68 to 91 per cent.

hosed. This was followed by two treatments with a 12.5 per cent solution of sodium hydroxide and a water rinse. Air was gently blown through the plates until they seemed dry and then the air pressure was raised to 1.5 p.s.i. and maintained there for 12 hours. Some improvement in permeability was obtained, but the plates were still clogged. The six plates removed from the tank were vacuum water washed from the top and blown at about 2 p.s.i. for 5 to 18.5 hours.

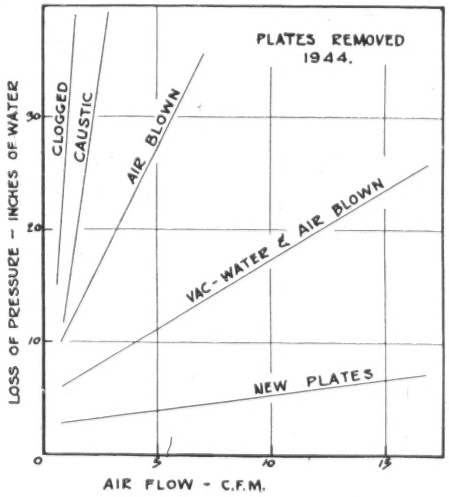


FIG. 3.—The caustic vacuum water wash-air blow system of laundering diffuser plates removed from aeration tank in 1944.

"Clogged"—Tank No. 1.

"Caustic"—Tank No. 1 after caustic treatment and water rinse.

"Air Blown"—Plates from Tank No. 1 were given a supplementary air blow after they were air dried.

"Vac-Water and Air Blown"—The "Air Blown" plates were treated again with caustic, then vacuum water washed, dried and reblown.

The results of each successive treatment are presented in Table 4, and the average results are shown in Figure 3. It is noted that plates removed in the spring of 1944 (Figure 3) were much more clogged than those removed in 1943. In fact, caustic treatment, water pressure rinsing and air blowing of the 1944 plates restored the permeability to the level of the "clogged" plates removed in 1943. After caustic treatment, vacuum water washing and air blowing of these severely clogged plates, however, the average loss of head through the plates was 8 inches of water at an air flow of 2.2 c.f.m. This amounts to 0.3 to 0.4 p.s.i. as compared with the normal loss through our new plates of about 0.13 p.s.i.

The laboratory tests indicate that the degree and uniformity of cleaning with vacuum water wash followed by air blowing are satisfac-

tory. Large scale experiments are planned to show the practicability of the process.

The application of vacuum to a water saturated plate is an efficient means of removing the clogging material for examination. The analysis of the solids removed from some of the plates are shown in Table 5. The treatment of these plates and the effectiveness of cleaning has been described in Tables 3 and 4. It is interesting to note that although the average weight of solids removed per plate by the application of the vacuum to the top of nine plates was 2.6 grams, the improvement in

TABLE 5. *Analysis of Material Removed from Clogged Plates*

Plate	Volume Wash Water (ml.)	Alkalinity as Na_2CO_3 Recovered in Wash (grams)	Total Insoluble Solids			Organic Carbon—Per Cent of Volatile Solids	Total Nitrogen—Per Cent of Volatile Solids	Ether Soluble—Per Cent of Volatile Solids
			Total (grams)	Volatile				
				Total (grams)	Per Cent			
(1)	(2)	(3)	(4)	(5)	(6)	(7)	(8)	(9)
53 Top Wash	460	0.015	2.94	0.326	11.1	47.9	6.8	6.06
Bottom Wash	450	0.014	0.41	0.164	40.0	85.7	4.0	10.7
54 Top Wash	530	0.224	3.04	0.351	11.6	35.6	7.2	9.15
Bottom Wash	490	0.158	0.65	0.273	42.0	93.8	8.0	8.58
57 Top Wash	515	0.94	2.12	0.206	9.7	51.2	7.2	12.8
Bottom Wash	465	3.58	1.40	0.572	40.8	51.0	2.2	12.0
58 Top Wash	845	0.70	1.01	0.08	8.0		11.8	17.6
59 Top Wash	950	1.72	3.54	0.21	5.9	66.0		4.24
60 Top Wash	815	1.18	2.27	0.17	7.4	62.3	11.0	14.3
61 Top Wash	615	1.15	2.98	0.30	10.1	74.6	5.9	5.35
62 Top Wash	595	1.16	2.80	0.29	10.4	60.4	6.4	3.45
63 Top Wash	575	1.37	2.69	0.28	10.4	62.8	7.4	4.70
Average Top			2.60	0.246	9.4	57.6	8.1	8.4
Average Bottom			0.82	0.336	40.7	70.2	4.7	10.9

permeability was slight. This material from the top consisted mainly of fine sand and contained only about 10 per cent volatile matter. When the vacuum was applied to the bottom of three plates, an average of only 0.82 grams of solids per plate was recovered, but the increase in permeability was remarkable. These solids contained about 40 per cent volatile matter. The percentages of organic carbon, total Kjeldahl nitrogen and cold ethyl ether extract in the volatile matter are shown in Table 5.

For a physical examination, the material was separated into two fractions, the easily settleable solids or sediment and the lighter suspended matter. The ash of all the samples had a deep brown color typical of high iron oxide content. The lighter suspended solids seemed to be composed of many small crystalline particles covered with amorphous matter.

The sediment from the top consisted mainly of particles having a diameter of 50 to 80 microns with some larger particles 80 to 400 microns in size, and just a few of a diameter of 400 to 600 microns. The particles were colorless to light brown with smooth surfaces and irregular shape resembling sand grains. The particles in the sediment fraction from the bottom wash were smaller in size, mainly 20 to 50 microns in diameter and were frequently covered with amorphous matter to give them a ragged appearance.

Summary

The air diffuser plates at the Wards Island sewage treatment plant, which are permanently grouted into place, have become so badly clogged that the usual treatment by brushing and caustic soda is no longer satisfactory.

Because of the need for a more efficient means of cleaning plates in place, two plate-testing boxes were constructed and laboratory studies made. Treatment of diffuser plates with chromic-sulfuric acid, sodium hydroxide or burning alone was unsatisfactory.

If the plates are not too badly clogged, treatment with chromic-sulfuric acid or caustic soda supplemented by air blowing of the dry plates does restore much of the permeability. The use of chromic-sulfuric acid on plates grouted into place with concrete is impractical.

When plates are badly clogged at the top and bottom, vacuum water wash of the top of caustic treated plates followed by blowing the dried plates at a pressure of about 2 p.s.i. for 5 to 18 hours was successful in restoring the permeability. Vacuum water wash removed the sandy material from the top of the plate and the air blew out or redistributed the clogging material at the bottom.

POROUS TUBE AIR DIFFUSERS *

By Frank C. Roe

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This discussion is the first known attempt to assemble basic information on porous tube air diffusers for the consideration of engineers and plant operators. It is primarily intended to show that diffuser tube aeration is highly effective and economical. There are some fundamental differences between diffuser tube and horizontal plate diffusion which will be indicated. The variations between different systems or designs of tube diffusers will also be discussed.

History of Air Diffusion

When the activated sludge process was introduced back in 1914, various types of air diffusers were considered. Early tests at Milwaukee of perforated pipe, porous wood and other porous materials indicated that porous ceramic plates were the most practical for large plants. Permeability could be controlled within sufficiently narrow limits to provide uniform aeration in tanks. Thus, horizontal porous plates became the first accepted means of air diffusion.

Upon the theory that more efficient oxygenation is obtained from small air bubbles, early porous plate diffusers were made of fine grade (low-permeability) material. In fact, perforated pipe diffusers which dispersed relatively large bubbles were replaced with porous diffuser plates at America's first activated sludge plant at San Marcos, Texas, to provide better aeration with less air.

As more plants were built, operating experiences created changes in the type or design of air diffusers. One of these early developments was the utilization of porous ceramic type tubes about 1928. The principal advantage was that they could be removed and serviced more easily than fixed, cemented-in-place, diffuser plates. This was of especial advantage to smaller plants where servicing would be desirable without dewatering tanks, often accompanied by reduction or loss of aeration treatment. It was also believed that the elevated position of diffuser tubes would save power, which will be discussed later.

Among the early activated sludge plants utilizing porous tube diffusers were those at Woonsocket, R. I., and Madison-Chatham, New Jersey. In these plants the tubes were suspended in pairs with axis parallel to the side walls. A practical method of tube assembly illustrated by Figure 1 was developed by the Link-Belt Company. This equipment is still manufactured and used in many plants as a standard method of diffuser tube assembly. A valve is normally used on the branch air line to each assembly to control air.

* Presented at the Spring Meeting of the New England Sewage Works Association, Boston, Mass., May 2, 1945.

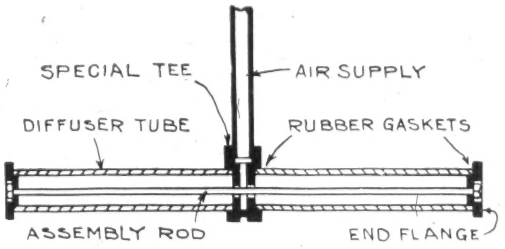

FIG. 1.—Diffuser tube assembly (Link Belt Company).

The installation at Woonsocket utilized a tank design patented by Henry E. Elrod of Houston, Texas, and assigned to the Link-Belt Company. This idea is illustrated by Figure 2. The novel feature is that

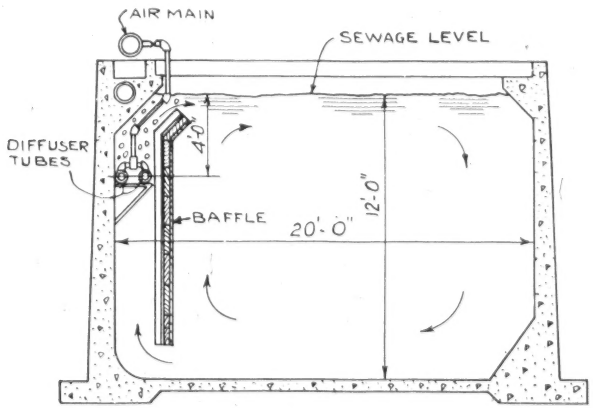

FIG. 2.—Cross section of "Elrod" (Link Belt Co.) spiral flow aeration tank.

sewage is forced up in the chamber behind the baffle and is hence replaced at the bottom—the well known air-lift principle. The rate of displacement is sufficient to maintain adequate spiral circulation in the main portion of the tank. By locating the tubes in an especially elevated position, air pressure is low and a power saving is presumed. Probably this feature overshadowed, at the time, the advantage that the diffusers were much more conveniently accessible. The Elrod design was utilized in 1932 at San Francisco, Calif.; later at New Britain, Conn., and elsewhere.

The more simple design illustrated by Figure 3 with tubes located near the bottom of the tanks was utilized at the early Madison-Chatham, N. J., plant and later in many other plants. It proved more popular

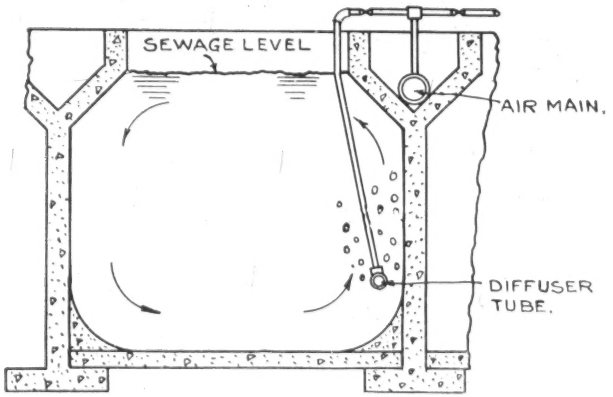

FIG. 3.—Cross section of early plain aeration tank using tubes.

than the Ehrod design because lower air quantity requirements appeared to compensate for slightly greater air pressures.

DEVELOPMENT

Air diffuser facilities and porous tube equipment particularly has kept pace with the popular growth and developments in the activated sludge process and other aeration applications. There are now some 400 diffused air installations in the United States, of which approximately 40 to 50 per cent utilize porous tubes. In the last 5 years, over 80 per cent have employed tubes.

Developments of porous tube equipment have taken two general courses: (1) improvements to increase efficiency and (2) improvements to simplify servicing.

1. *Improved Designs or Type to Increase Efficiency*

Early designs utilizing suspended tubes parallel with the tank axis usually required a little more air for a given result than was required with diffuser plates. Requirements in excess of 1.0 cu. ft. per gal. were the rule rather than the exception for activated sludge aeration. This was probably due to the comparatively narrow stream of air bubbles rising above the tube diffusers and being forced against the tank wall by the circulating current with more or less coalescing effect (see Figure 4). More rows of tubes introducing air in a wider area of the tank would have improved aeration, but such an arrangement was not practical with tubes suspended parallel to the tank axis; it would have also been expensive and inefficient.

The inefficiency of early tube designs led to a development by the Chicago Pump Co. wherein tubes are located at right angles to the

tank axis as shown by Figure 5 to give the so-called "wide band" of freely rising air bubbles. It is a notable fact that diffuser tubes installed in this manner, as further illustrated by Figure 6, provide unusually good aeration with exceptionally low air requirements. At Gary, Ind., for example, where the sewage strength is 130 p.p.m. 5-day B.O.D., a 92 per cent removal is accomplished with 0.41 cu. ft. of air per gal. in a 3.9-hr. aeration period.

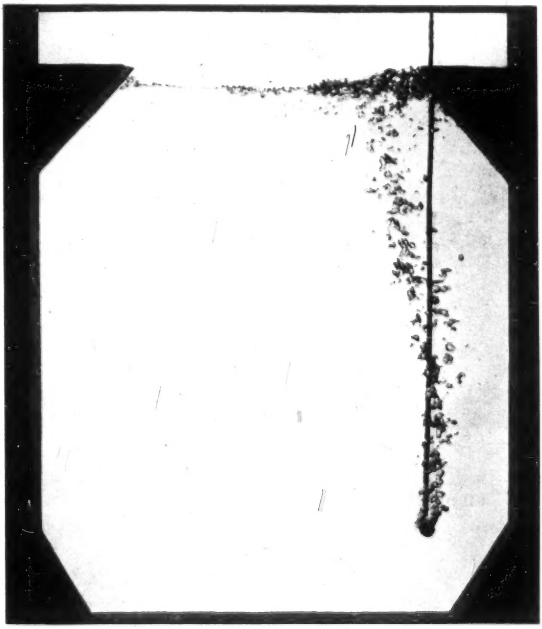

FIG. 4.—Narrow stream of coalesced bubbles from a single tube.

An incidental improvement of the Chicago Pump Co. equipment is the control orifice within each tube adaptor or assembly as illustrated by Figure 7. This assures uniform delivery of air to each tube, eliminating the individual valve control required with early tube assemblies. It will also prevent escape of large quantities of air in case of tube breakage or gasket failure.

2. *Improvements to Reduce or Simplify Servicing of Diffusers*

An early advance was the change from the "fine" to the "medium-coarse" grade of porous diffusers, which change applied to plates as well as tubes. Larger pores result in a lower rate of clogging, better

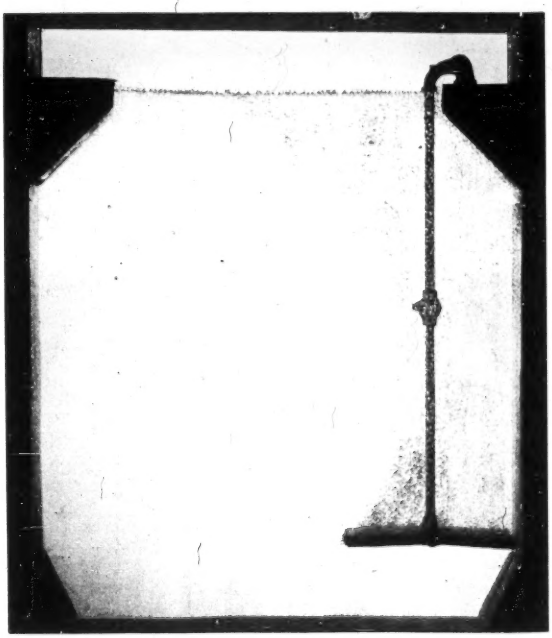

FIG. 5.—"Wide band" diffuser tube system.

response to cleaning methods and provide lower average operating pressures. Studies by Beck at The Sanitary District of Chicago proved that there was practically no increase in air bubble size resulting from this change. Hence, there is little loss in oxygenation efficiency.

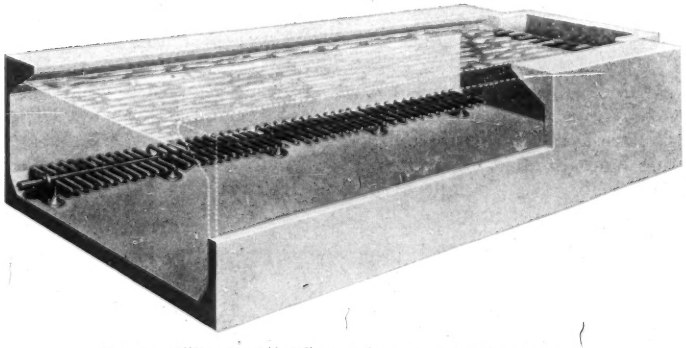

FIG. 6.—"Wide band" diffuser tube system (stationary type).

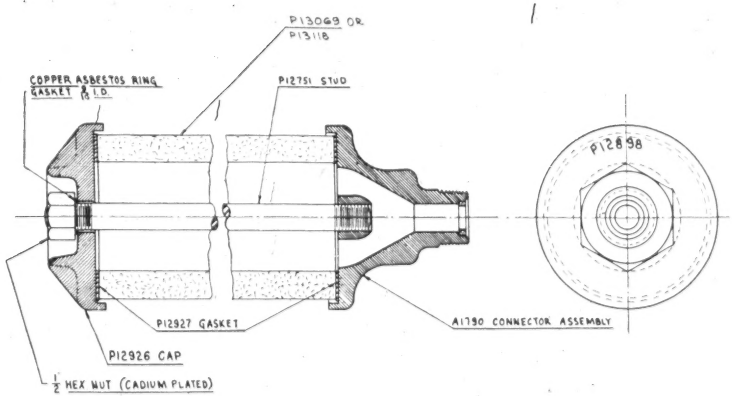

FIG. 7.—Cross section of Chicago Pump Co. diffuser tube assembly, showing the orifice.

Concerning accessibility for cleaning and ease of removal, diffuser tubes as originally introduced were superior to plates. A further outstanding improvement along this line has been the Chicago "Swing Diffuser," illustrated by Figure 8. The simplicity of tube removal from tanks is apparent. This design also permits simple increase, decrease or change of location of diffuser tubes—all without tank dewatering.

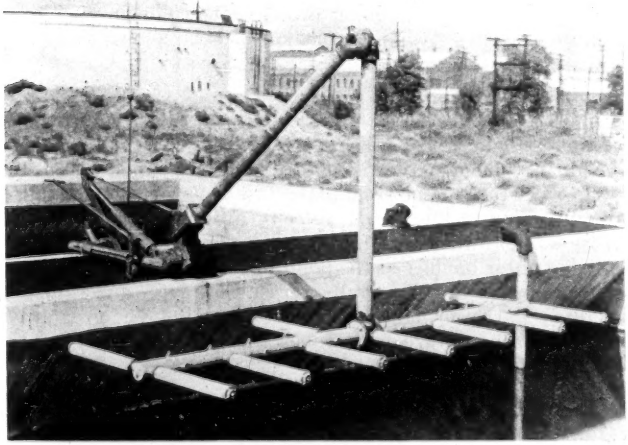

FIG. 8.—Swing diffuser tubes (East Chicago, Ind., sewage treatment plant). Hydraulic hoist is in position.

Just within the past year, The Carborundum Co. has developed a new, light weight, porous tube for the Chicago "Swing Diffuser." This permits an increase in the number of tubes that each swing unit can handle with an economical hoist, which eases the servicing job and decreases diffuser equipment cost. The superior strength of such tubes has been retained and uniformity of diffusion is excellent.

Advantages of Diffuser Tube Aeration

This portion of the discussion is based on some proved theories of air bubble dispersion as well as on laboratory experimental work. It is intended to outline the advantages of diffuser tube aeration and in this respect some comparison is made with horizontal diffuser plate aeration. Plant scale proof of the economic advantages of diffuser tube aeration over horizontal diffuser plate aeration, under identical conditions, has not been established so far as is known but The Sanitary District of Chicago is conducting such comparative studies at the present time.

It will be noticed that the term "horizontal plate diffusion" has been used thus far. The use of *vertical* diffuser plates was introduced and patented by W. M. Piatt some 10 years ago and is now being offered by the Pacific Flush Tank Co. Several successful installations are in operation, notably the first installation at Durham, N. C. The comparisons of this discussion are not intended to apply to the vertical plate equipment which also overcomes some of the apparent disadvantages of horizontal plate equipment. Incidentally, the comparative work by The Sanitary District of Chicago includes an installation of the Pacific Flush Tank Co. vertical plate equipment.

Believing that the advance in design of diffuser tube equipment already outlined is proved by plant practice, the following points will be based on the so-called "wide-band" type of equipment.

1. *Contact Volume*

A comparison between horizontal plate diffusion (Figure 9) and modern suspended diffuser tube diffusion (Figure 5) indicates that the actual contact volume of the rising stream of air bubbles from tubes is more than twice the volume from plates. The lower volume from plates is apparently due to the higher velocity around the periphery of the tank cross section, which results from the plate location and relatively narrow band of air bubbles at the point of diffusion. The aeration tank liquor seems to sweep horizontally across the plates and compress the bubbles into a narrower bank along the tank wall. The greater contact volume of the air mixture from tubes will thus contribute to greater oxygen absorption.

2. *Detention Time of Air Bubbles*

Based again on the illustrations comparing horizontal plate diffusion with tube diffusion, it is apparent that there is a greater detention time

in the case of tube diffusion. Since $Q = AV$, the velocity in the case of "wide-band" tube diffusion is obviously very much lower, thus providing a longer time of oxygen contact with mixed liquor or sewage. This phenomenon will also increase the oxygen absorption when using modern tube diffusion as compared with plate diffusion.

3. *Circulation*

There is actually a better tank circulation characteristic with "wide-band" diffuser tubes than with horizontal diffuser plates. The air-lift

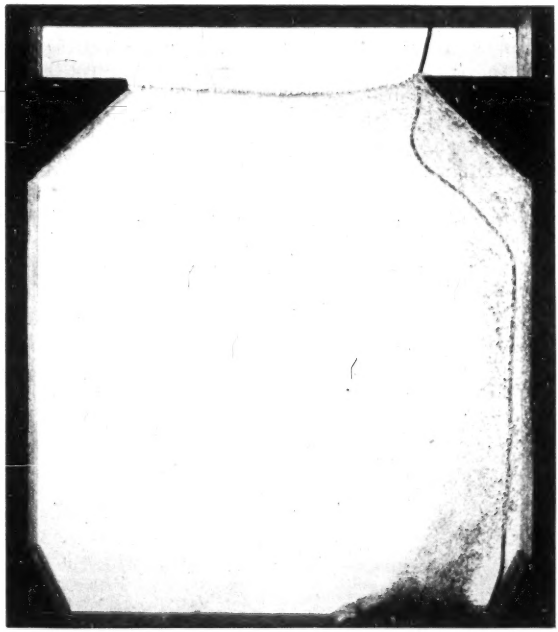

FIG. 9.—Air diffusion from horizontal plates.

effect is over a wider area so that the entire tank contents are being moved uniformly. With horizontal plate diffusion as well as the older longitudinal tube diffusion, there is apt to be a "spout" effect.

Operation reports on modern diffuser tube installations show that velocities are more than adequate to prevent any accumulation of solids in tank bottoms.

4. *Center Core*

The modern diffuser tube system eliminates center coring in aeration tanks from all practical consideration because a greater volume of the tank contents is constantly rolling.

5. *Operating Head*

The location of tube diffusers approximately 2 ft. above aeration tank bottoms saves about 7 to 10 per cent on blower power requirements as compared with horizontal diffuser plate power requirements. This economy will effect a substantial accumulated saving through the life of an installation.

Characteristics of Tube Diffusion

There are fundamental differences in the nature of air diffusion from tubes as compared with horizontal diffuser plates. In the first place, the vertical flow of mixed liquor or sewage past suspended diffuser tubes provides a better "wiping" action, resulting in small air bubbles. In the case of horizontal diffuser plates, release of bubbles depends to a large extent on overcoming surface tension.

The effective area of diffuser tubes will vary with the flow of air because of the slight difference in head between the top and bottom of the tube. With a horizontal diffuser plate, the effective area remains constant. Thus, an increase in rate of diffusion from a given tube puts more area into use and there is little increase in bubble coalescing. An increase of air from a horizontal diffuser plate can only increase the coalescing effect.

In consequence of the foregoing phenomena plus the fact that the air stream from modern diffuser tube equipment is unrestricted, rates of air diffusion from tubes can be higher than from horizontal plates.

Based on experience to date, a 24-in. long tube from 2½ in. to 3 in. in diameter can provide efficient diffusion at a rate of 4 to 8 c.f.m. The average for design purpose in the case of activated sludge aeration is approximately 6 c.f.m. per tube.

The number of diffuser tubes required for a given condition can be established directly on the foregoing basis, knowing the total probable air requirements. In the case of a design using horizontal diffuser plates, it has been necessary to establish diffuser area requirements on the basis of the limited efficient rate of diffusion, which is about 3 c.f.m. per sq. ft., maximum.

Diffuser Tube Specifications

It has been suggested that present standard specifications developed by porous media manufacturers are slightly confusing to engineers. They do not adequately tie in permeability with wet pressure loss, which is the important factor in design, especially with orifice control.

The present standard dry permeability test was established because it was, and is, the only practical means of checking each unit in the factory. Permeability is inversely proportional to wet pressure loss so diffusers with uniform pressure loss characteristics are obtained. It is a fact, however, that the wet pressure losses of different makes of diffusers are not identical on units of similar permeability.

To avoid this slight confusion and to provide tube equipment that will conform precisely to design, an addition to standard specifications is suggested, as follows:

Permeability and Head Loss:

To assure uniform tube operating characteristics the selection of the tubes at the point of manufacture shall be controlled on the basis of the permeability test. The manufacturer shall establish the permeability which he will use to produce tubes which will be acceptable on the basis of the head loss specifications below, and all tubes shall be rejected which do not fall within the maximum allowable deviation of plus or minus 10 per cent of the mean permeability which has been selected.

The diffuser tubes shall have a head loss such that when they are tested submerged in water, with a temperature of 70° F. plus or minus 2° and with air at a temperature of 70° F. plus or minus 5° F., the head loss through the diffuser tube and adaptor together with the flow controller or orifice which go to make up a diffuser tube assembly shall not be more than —— inches of water pressure at a flow rate of 4 c.f.m. per tube, nor more than —— inches of water pressure at a flow rate of 8 c.f.m. per tube. The head loss test shall be conducted on ten tubes selected at random from each batch of 1,000 tubes which have been accepted from the tube manufacturer on the basis of the permeabilty control test as outlined above. If the tests indicate that one or more of these tubes are not acceptable on the basis of the head loss determination, 10 per cent of the batch shall be tested and if 10 per cent of these are not acceptable, the entire batch shall be tested for head loss and the additional cost shall be born by the contractor.

The present specification covering "uniformity" by visual inspection has proved adequate for all practical purposes. It is of interest to note, however, that testing equipment developed in the Chicago Pump Co. laboratory (Figure 10) actually measures the air discharged

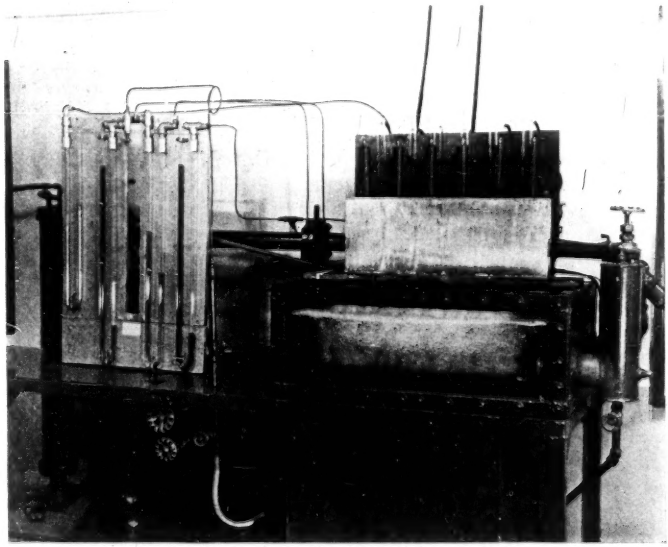

FIG. 10.—Diffuser tube testing tank in the laboratory of the Chicago Pump Co.

from each of six equal tube sections. This test has proved to be a positive check on visual inspection of "uniformity."

Summary and Conclusions

The various points covered in this discussion indicate that modern diffuser tube aeration possesses some outstanding advantages. This seems to apply to operation efficiency characteristics as well as to equipment maintenance. There is no substantial increase in installed cost compared with horizontal plate diffuser equipment so that apparent differences in operating cost warrant thorough consideration.

The foregoing opinion is advanced from a neutral point of view. So far as the writer is concerned, aeration with any type of porous diffuser is of interest regardless of whether plates or tubes are used. It is realized that porous diffuser equipment must stand the test of time in competition with other equipment, aeration methods and even with other sewage treatment processes.

TREATMENT AND DISPOSAL OF DIGESTION TANK SUPERNATANT LIQUOR *

By C. V. Erickson

Research Department, Pacific Flush-Tank Company, Chicago, Ill.

The Supernatant Liquor Problem

The addition of relatively large volumes of thin raw sludge to digestion units and the withdrawal of smaller volumes of more concentrated digested sludge result in the necessity for periodic withdrawal of excess liquor from the digesters.

Despite the exercise of care by plant operators to draw off only the best liquor, it is usually still high in solids, great in volume and it imposes a heavy B.O.D. and solids load on the portion of the plant to which it is returned. Due to its high B.O.D. and solids content and probably to the specific nature of its bacterial flora, supernatant liquor has a tendency to cause disturbance of the primary settling tanks. This causes a sludge of higher moisture content to be transferred to the digester and results in a greater volume of supernatant liquor to be returned. Thus a self-pyramiding cycle is set up.

At Buffalo, N. Y., for example, the quantity of solids returned to the treatment process in the supernatant liquor drawn from the digesters has, at times, amounted to as much as 40 per cent of the amount of raw solids coming into the plant in the raw sewage.

It is easy to see why many plant operators regard supernatant liquor as their No. 1 problem.

The magnitude of the problem and the difficulties presented will in large measure be dependent upon the factors of safety that have been provided in the design of the individual plant or the extent to which the applied load approaches the ultimate capacity of the various plant units. There are, however, a number of factors which have a direct bearing upon the quantity of excess digester liquor which must be withdrawn and handled in any treatment plant.

Variations in Volume

Variations in the volume of supernatant liquor are due primarily to the relative concentrations of raw and digested sludges entering and leaving the digester. It is therefore axiomatic that the primary consideration in reducing the excess digester liquor is to reduce the liquid volume of the sludge added to the digester by increasing its solids concentration.

The type of treatment process employed has a marked effect on the concentration of solids in both raw and digested sludges. In making comparisons between the solids content of sludges produced in various

* Presented by L. L. Langford at Spring Meeting of the New England Sewage Works Association, Boston, Mass., May 2, 1945.

processes it is assumed that grit is not present in any appreciable amounts. Approximate concentrations of sludge solids that may be expected in conventional treatment processes are:

Plain sedimentation:
Raw sludge—4 to 6 per cent solids.
Digested sludge—8 to 12 per cent solids.
Sedimentation and trickling filter:
Secondary tank sludge—3 to 4 per cent solids.
Mixed primary and secondary tank sludge—4 to 6 per cent solids.
Digested mixed solids—6 to 10 per cent solids.
Sedimentation and activated sludge:
Waste activated sludge—0.5 to 1.0 per cent solids.
Mixed primary and waste activated sludge—2 to 3 per cent solids.
Digested mixed solids—4 to 6 per cent solids.
Chemical precipitation:
Fresh solids—about 5 per cent.
Digested sludge—about 10 per cent.

Figures for sludge from high rate trickling filter plants will tend to approach those of the activated sludge process.

The presence of industrial wastes will have considerable effect on sludge solids concentration, depending on the type and proportionate quantity of such wastes in the raw sewage. This is a subject in itself and is merely mentioned here to recognize the importance of its consideration in digester design and operation.

The experience of operators will, we believe, bear out the figures given above. We must recognize the difference in volumes represented in pumping the various kinds and concentrations of sludges to digestion units. For instance, in order to transfer equivalent weights of dry solids, a 2 per cent solids concentration of mixed primary and waste activated sludge would require the pumping of a volume three times as great as the volume of a 6 per cent solids concentration of primary tank sludge.

Control of the duration and frequency of raw sludge pumping can accomplish much in minimizing the amount of excess liquid added to digestion units. As the amount of sludge deposited in the hoppers of primary settling units will vary from day to day, the time required to transfer this sludge to the digestion units will not be a fixed period each day. Weather conditions, season of the year, intermittent operation of certain industries, and changes in the wastage of excess activated sludge are some of the factors that cause daily variations in sludge quantities.

From an ideal viewpoint, frequent pumping of small amounts of thick sludge which has been allowed to concentrate as much as possible in the settling tank would minimize the addition of liquid to the digesters. On the other hand, it is desirable to remove as much of the deposited solids as is practicable from the primary settling units sufficiently often to keep such material from becoming septic and rising to the surface to be carried out in the effluent.

From a practical angle, therefore, any attempts to limit the amount of liquid going into the digesters will necessarily be along the line of an intermediate procedure as compared with the two mentioned above. What, if any, limit there might be on the thickness of sludge that can be economically and satisfactorily heated and digested has not been established. The concentrations of solids procurable with methods and equipment now in use have apparently not been too heavy to be handled in digesters, so we may continue for the time being, at least, to work toward a reduction in the moisture content of sludge added to digestion units.

Where sludge is pumped directly out of the settling tank hoppers, sampling facilities on the pump or the line can be tried frequently during transfer to avoid pumping excessive amounts of liquid. As pointed out earlier in this paper, the amount of liquor to be treated and disposed of can be limited to some extent by care in the pumping of raw sludge. Stopping pumpage before the sludge thins out, and pumping frequently at low rates are methods of delivering thick sludge to the digesters.

The experience at Aurora, Illinois, in 1936 and 1937 is typical of what can be accomplished through careful control of raw sludge pumping. There, over a period of several months the solids content of raw sludge pumped to the digesters had gradually decreased from 5.5 or 6.0 per cent to 3.5 per cent because of excessive periods of pumping to clear the clarifiers of solids. By reducing the frequency and the duration of pumping periods and by overhauling the plows on the clarifier mechanisms the solids concentration was raised to 5.2 per cent, giving them an increase from 38 to 49 days in the displacement period in the digester.

In some plants relative elevations are such that gravity sampling lines extending from the hoppers through the wall to the pump room can be used to advantage in determining when to start and when to stop pumping of solids from the hoppers. At Ann Arbor, Michigan, an arrangement of this type gave improved control and resulted in reduced periods of sludge pumping.

Where sludge is drawn by gravity through a valve into a sump or wet well prior to pumping, carelessness in opening the valve too much or keeping it open too long may add excess liquid to the solids. Such an arrangement is sometimes equipped with a telescoping draw off pipe riser.[7] This permits regulation of the draw-off head, eliminates valve throttling and aids in drawing as heavy a sludge as possible into the sump or wet well for transfer to the digestion units.

Concentration units, situated between the settling units and the digesters, are in many instances used to advantage in thickening the raw sludge. Although this type of unit has not always been as effective as designers and operators have desired or hoped it might be, it should be emphasized that oftentimes a small percentage increase in the solids content of sludge has accomplished a volume reduction of particular significance to the plant involved. For instance, a decrease in the moisture content of sludge from 98 per cent to 97 per cent results in having

to pump only ⅔ of the original volume, with a corresponding reduction in liquor to be handled as supernatant.

Local operation difficulties involved in the discharge of excess activated sludge to the primary settling units, for resettling with the primary solids, have encouraged investigations of methods for thickening waste activated sludge in separate units before adding it to the digesters.

The plant at Ann Arbor, Michigan, was able to secure some concentration of waste activated sludge by chlorination and settling in an isolated final settling tank. Use of the tank for this purpose was discontinued when it was needed for final settling of additional main plant flow.

At the same plant, laboratory experiments on the concentration of waste activated sludge with the use of chemicals led to the construction of concentration and decanting tanks. These will be used for plant scale studies of the concentration of excess activated sludge prior to its discharge into the digesters.

So far, means have not been devised that are uniformly effective in concentrating the solids in waste activated sludge in such a way that the separated solids and liquid can be handled in a practical manner. Treatment with certain chemicals may cause the solids to float instead of settle, thus complicating the separate handling of liquid and solids.

Attempts to thicken certain types of sludge or mixtures of various sludges have sometimes been ineffective because gasification caused flotation of a substantial portion of the solids. This particular difficulty was encountered in some of the rather extensive testing work carried on at the Cleveland Southerly plant on sludge which had been pumped to this plant from the Easterly works.

Some measure of success has been achieved in supplementing overloaded Imhoff tanks with heated digesters, with a resultant reduction in supernatant liquor to be handled. The digestion compartments of the Imhoff tanks act as concentration units and the concentrated sludge is transferred to the heated digestion units. Examples of installations of this type are Elgin, Ill., the Westerly plant at Cleveland, Ohio, and the Elyria, Ohio, plant.

Definition of Supernatant Liquor

An attempt has been made to outline the factors affecting the volume of this material which is widely referred to as "supernatant liquor." It might be well at this point to present a few thoughts which may initiate a discussion and help to arrive at a definition as to what constitutes supernatant liquor.

The dictionary definition of the word "supernatant" is "floating uppermost or above something. Said especially in chemistry of the liquid from which a precipitate has been thrown down."

The definition of the word "supernatant" indicates that such a liquor is an overlying one. Exception might be taken to applying the word "supernatant" to digester liquor in view of the fact that oftentimes the definite separation of a layer of relatively clear liquid may

occur somewhere in the digester other than at or near the top. It has been and might more properly be referred to as "digester liquor." However, our time would be applied to better advantage by overlooking this distinction and attempting instead to come to some agreement as to what such liquor really is.

It might be said, for example, that supernatant liquor is anything taken out of the digester which is neither scum nor sludge nor gas. This places no limitations on its solids content and is not an adequate definition.

One might say also that it is the layer of material which occurs in a digester between a floating scum layer and a settled sludge layer. Too often, however, the material may not be so located, and it may be difficult to establish the presence of any definitely separate layer.

As to source, we could designate supernatant liquor as being the excess volume of liquid accumulating in digestion units as a result of adding quantities of relatively thin raw sludge and withdrawing smaller volumes of thicker digested sludge. This statement does not differentiate between a good and bad quality of liquid, nor as to its solids content.

We might, perhaps, draw an analogy to a definition of digested sludge in saying that, to an operator, supernatant liquor is excess digestion tank liquor in which the concentration of solids and other characteristics are such that the liquid is amenable to adequate treatment with the particular facilities available for that purpose, just as an operator would consider digested sludge as being solids decomposed to the extent that they are capable of being handled economically and without nuisance on the drying beds or other dewatering facilities.

An indirect definition of supernatant liquor, bringing out something as to quality of the liquid, could be suggested by calling it the excess volume of liquor accumulating in a digestion unit which shows evidence of turning out a well digested sludge, or of doing an effective job of digestion as measured by:

1. Normal volume of gas production.
2. Normal quality of gas.
3. pH near 7.0.
4. Freedom from unpleasant odor.
5. Breakdown of water-binding properties indicated by good drainability of the digested sludge.
6. Low volatile and high solids content.
7. Volatile acids content under 2,000 and preferably under 1,000 p.p.m.

Such a liquid might, however, be so high in solids content that one would be reluctant to refer to it as a supernatant liquid or to attempt to handle it as such.

The statement that supernatant liquor is the thinnest liquid in the digester, no matter where its location or what its solids content might be, is stretching the point somewhat, particularly in the case of heavily

loaded units where practically no variation in solids content is evident from top to bottom of the unit. In many such cases it would amount to the designation of sludge as supernatant.

Perhaps the shortcomings of the definitions already mentioned could be overcome by specifying certain limits on several characteristics that would distinguish supernatant liquor from sludge and that would enable operators at various plants to be in agreement on whether they actually have a supernatant liquor or merely a thin sludge to handle and treat. It is believed that there is not now in existence or general use any suitable standards for designating what is meant by "supernatant liquor."

Characteristics, for each of which limiting values could be established to designate supernatant liquor as such, might include:

1. Total solids content of the liquid.
2. Percentage reduction from the original volatile solids content of the sludge added to the digesters.
3. Amount of suspended solids as determined by either a gravimetric or a volumetric method, or both.
4. Volatile acids content.
5. pH.
6. Bacteriological characteristics.

The question can be raised as to whether percentage reduction from the original volatile content or whether the actual volatile content of the liquor should be used as one criterion. In a case where raw sludge of an unusually high volatile content is digested, the digested sludge and liquor may still have a rather high volatile content while otherwise showing evidence of being well digested and inoffensive material. Here, per cent reduction would be the preferred measure. Volatile content of the final material, however, would be a better basis for comparisons between various plants. It might also be found that unless the volatile content of the liquor were in the lower ranges, the liquor could not be readily treated. Further investigations are probably necessary to make a choice in this respect.

The suspended solids determination might take the form of a test to see what relative volumes of liquid and solids would separate after standing quietly for a designated period of time. Objections to such a test would include the probability that some solids would float and some settle, and the fact that differences in bulkiness of the solids from various digesters would not reflect corresponding differences in weights of solids on a dry basis.

For the purpose of encouraging a discussion that may lead to a tentative agreement or understanding as to the makeup of supernatant liquor, the following limits on certain characteristics are suggested:

1. Total solids content of not more than 10,000 p.p.m.
2. Not less than 60 per cent reduction in volatile solids content of the raw sludge on a dry basis, or having, on a dry basis, not more than a 50 per cent volatile solids content in the liquor.

3. Volume of suspended solids occupying not more than 50 per cent of the original volume of a test sample of supernatant liquid standing quietly for one hour.

For instance, referring to the suggested requirement as to reduction in volatile solids content, if we start with raw sludges of 70 per cent and 85 per cent volatile content, a 60 per cent reduction in volatile solids content would give final volatile contents of 48 per cent and 69 per cent respectively, in the digested materials. In order to end up with digested material having a 50 per cent volatile content, a reduction of 57 per cent in the original 70 per cent volatile sludge and of 82 per cent in the original 85 per cent volatile sludge would be required.

Handling and Withdrawal of Supernatant Liquor

Having established the presence in the digester of liquor that can be called supernatant, some consideration of the means for handling and withdrawing it is in order.

Fixed Cover Digesters

In fixed cover digestion units the arrangement is such that excess liquor must be removed from the digester at the same time and at the same rate at which the raw sludge is added.

In single digesters of this type, supernatant is taken off at the top of the unit, while in the series arrangement, sludge is displaced automatically from the primary to the secondary digester at the same rate of flow as raw sludge is being pumped into the primary. Supernatant liquor is also simultaneously displaced from the secondary digester.

Floating Cover Digesters

In the floating cover type of digester, whether single or series units, the drawoff or transfer of supernatant liquor or sludge need not be made each time raw sludge is pumped. Considerable control is afforded the operator in selecting suitable times for the withdrawal of the best supernatant liquor.

The provision of multiple (usually 3 or more) take-off lines at different levels in the digester gives the operator still more leeway in selecting the best available supernatant liquor for removal. Even this flexible arrangement is not entirely satisfactory, for often the best liquor available may be at an elevation between these draw-offs. Furthermore, operators must draw the best liquor available through valves which are limited in the amount that they can be throttled without clogging. Supernatant liquor must, therefore, be drawn at a relatively high rate to avoid clogging of the draw-off valves. A high withdrawal rate is undesirable from the point of view of its treatment and return to the plant process.

Multiple Digesters

Multiple digesters have been provided in order to reduce the solids content of supernatant liquor. The provision of two-stage operation

gives a more quiescent secondary digestion capacity in which the solids are allowed to concentrate and the liquor to separate, due to the fact that comparatively little gas lifting action is present to disturb such stratification.

It should be realized, however, that inasmuch as fully 80 to 90 per cent of the total gas production and consequent digestion of solids takes place in the primary digester, it is not economical to provide an excessive capacity in the secondary digestion units.

Where multiple digesters are provided, flexibility of operation should be incorporated in the design in order that the relationship between primary and secondary units may be readily changed to suit the operating conditions encountered by the operator.

In looking backward over the years of sewage treatment experience, the supernatant liquor problem seems of comparatively recent origin. It has apparently developed with the advent of separate sludge digestion. With the Imhoff tank and standard trickling filter plants which were so prevalent some few years ago, we were not conscious of any supernatant liquor problem but the Imhoff tank performed the same functions in the digestion of solids settled from the sewage. We might, therefore, in looking for a better method of handling supernatant liquor review and analyze the function of the Imhoff tank in separating and handling supernatant liquor.

As solids drop from the flowing through compartment into the digestion chamber, a certain volume of liquid is displaced from the digestion compartment. Its only outlet is to pass up through the slots into the flowing through compartment and out with the effluent to the secondary process. In other words, withdrawal of excess digester liquor from Imhoff tanks is accomplished automatically at a continuous and a low rate of flow.

Because of this low rate of displacement, secondary treatment units handling effluent from Imhoff tanks have been able to turn out a uniformly excellent quality of final effluent, even though the Imhoff tanks were not operating as well as they might have been.

Suggested System of Supernatant Liquor Withdrawal

In suggesting a system for the satisfactory withdrawal and handling of supernatant liquor from separate heated digesters, it would seem reasonable to conclude that it should simulate the conditions under which such liquor is released from Imhoff tanks.

A satisfactory system should include such characteristics as:

1. Continuous or long-period removal of the liquor at a low rate of flow.
2. The ability to obtain the best liquor in the digester or storage unit and remove it, regardless of its location.

Equipment is available which provides a simple and automatic means of withdrawing the best supernatant liquor from digestion tanks

at a slow continuous rate. This equipment is described and illustrated by Schlenz (*This Journal*, **16**, 3, 504 (May, 1944), also **16**, 5, 1082 (Sept., 1944)).

In operation, when supernatant liquor is withdrawn from the tank, the liquor sufficiently low in suspended solids passes through the selector slots at any point or level in the tank where such liquid is located, at a low rate of flow controlled by means of the gauge and sight glass. The slots in the selector are so shaped that solids suspended in the supernatant liquor will initially tend to collect and adhere around the edges of the slots, thereby reducing the area of same. With the aid of a mat of solids thus formed, an effective straining action occurs. It is desirable to consider the device merely as a means of selecting the clearest liquor to be withdrawn from the digesters and not as a means of treatment. Facilities for variation of the draw-off rates and sampling of the liquor are provided in this closed withdrawal system. Thus, it is possible to determine and use the proper slow continuous draw-off rate that will make room for new additions of solids on the next day.

At Cleveland, Ohio, a selector was installed as a demonstration unit in one of twelve 95-ft. hexagonal digesters. It was found that to accommodate the daily additions of raw solids it was necessary to operate the supernatant selector at a continuous draw-off rate of only 27 g.p.m. This resulted in a reduction in solids content and an improvement in the average quality of supernatant liquor removed as compared with the average of the supernatant liquor withdrawn from the other eleven digesters in the system.

In addition to the selection of the best liquor in the digestion tank and the low rate of continuous withdrawal, it may still be found desirable to provide treatment for this supernatant liquor before final disposal or return to the main treatment processes.

Treatment of Supernatant Liquor

A number of methods have been employed in disposing of supernatant liquor after withdrawal from digestion units. Some of these methods are enumerated and discussed briefly as follows:

1. *Return to the treatment process* is a common method of handling such liquor. Usually it is discharged to the inlet of the plant for treatment along with the raw sewage.

The presence in the liquor of solids and bacterial flora from an anaerobic digester has a tendency to inoculate the fresh solids, and under suitable conditions may cause deposited material to rise to the surface. Such lifted material may be carried out in the tank effluent, increasing the load on the secondary process.

The nature of the solids in the liquor often is such that when mixed with the raw solids, a thin sludge is produced for pumping to the digesters. This greater volume of sludge necessitates the later release of increasing quantities of supernatant liquor, creating a vicious cycle.

In some plants, excess digester liquor has been returned to the secondary process to avoid the formation of thin sludge in the primary

tank hoppers. This eventually increases the amount of solids to be wasted from the secondary process after seeding requirements are satisfied, as in the activated sludge process. For example, at Ann Arbor, Michigan, supernatant liquor has been discharged into the influent conduit to the aeration tanks without harmful effect to the secondary process. An increase in the amount of solids wasted to the primary settling tanks was experienced, however.

2. *Discharge of supernatant liquor to drying beds* is an expedient rather than a method of treatment, for it soon causes clogging of the beds and is a source of odors.

3. *Chemical coagulation and settling* of supernatant liquor has been subjected to rather wide experimentation. Results have not been too encouraging, particularly from the points of view of cost and the volumes of sludge created.

4. *Sedimentation* of supernatant liquor has also been tried quite widely. Chlorination of the liquid, to prevent gasification and flotation of solids during the settling and concentrating period, has also been investigated. While some compacting of solids has been accomplished by this method and by means of mechanical thickeners, the water-binding characteristics of many sludges has prevented the attainment of striking results in this direction.

5. *Aeration* of supernatant liquor with raw sewage in preaeration channels or chambers ahead of primary settling tanks has not been particularly effective in relieving the usual difficulties encountered in returning digester liquor to primary tanks.

6. *Centrifuging of supernatant liquor*, under conditions so far experienced, is a cumbersome and relatively expensive method of clarification.

7. *Lagooning* may also be classed as an expedient, rather than a method of disposal of digester liquor. It is a source of odors and requires rather large areas of land.

In the investigation of processes involving settling of supernatant liquor for the purpose of removing the solids, it has been found that the settling action has not been satisfactory due to the presence of adhering and entrained gases in the suspended solids. It has therefore been suggested that if these gases could be removed from the solids in an effective way, sedimentation and subsequent clarification of the supernatant liquor would be possible.

Supernatant Treatment Utilizing Atomized Aeration and Settling

An effective method has been developed for removing the adhering and entrained gases in supernatant liquor solids by means of an atomized aeration and settling system such as is described and illustrated by Schlenz (*This Journal*, **16**, 3, 504 (May, 1944), also **15**, 5, 1018 (Sept., 1943)).

The operation of the treatment unit is as follows: The atomizing action takes place in the aerator box which is mounted above the center of the tank. The top of the aerator box is connected by a duct to an

exhaust fan, and the bottom plate of the box is equipped with a number of short open pipes called "tuyeres." In the center of this bottom plate is a discharge tube extending downward.

The fan exhausts air from the aerator box, setting up a vacuum therein. The only source of air for the fan is the open ends of the tuyeres. Air rushing through them draws supernatant liquor up with it, giving the appearance of a miniature waterspout under the center of each operating tuyere. On reaching the top of the tuyeres, the liquor breaks up into a spray of finely divided particles in intimate contact with the entering air. Gas bubbles entrained in the suspended solids or dissolved in the liquor are released in the existing vacuum. Separation of the aerated liquor particles and the air takes place within the box, the liquor discharges through the central bottom outlet, and the air is drawn off through the takeoff duct and fan.

Separation of solids from the liquor takes place in the settling portion of the tank. Settled solids are drawn from the sludge hopper of the tank at intervals, the frequency and duration of the draw-off periods being dependent upon the solids content of the raw liquor. It is desirable to draw as thick a sludge as possible from the hopper, and yet not to permit an excessive accumulation of settled solids in the unit as they might be carried off in the treated effluent.

As the aeration box circulates liquor at a much greater rate of flow than the influent rate of flow through the orifice box, the raw liquor is given several "turnovers" or aeration cycles in the treatment process. The settled solids may be returned to the digesters or discharged to drying facilities.

Some typical operating data have been plotted in Figure 1 to demonstrate the results obtained in treating supernatant liquor by this method at three different plants, in each of which the digesters were handling mixtures of fresh solids and waste activated sludge solids. The Cleveland and Camp Shelby plants have diffused aeration and the Geneva plant has mechanical aeration. The curves shown have been drawn for only the Cleveland, Ohio, data. Data for the other two plants have been plotted to show their position with respect to the Cleveland curves. In other words, the Cleveland curves have not been altered to correspond with the data of the Camp Shelby and the Geneva plants.

It will be noted that the data for the Camp Shelby, Mississippi, unit cover a range of rather weak supernatant liquors up to about 2,000 p.p.m. of suspended solids, while the data for the Cleveland Southerly experimental plant are spread over a much wider range of solids concentration in the raw supernatant liquor.

It was found during the Camp Shelby testing work that, in the case of the weaker supernatant liquors handled there, dissolved oxygen was present in the effluent from the unit in amounts varying from a trace up to about 2 p.p.m.

From these curves it can be seen that in the range below about 10,000 p.p.m., or 1 per cent solids (either total or suspended), removals were strikingly consistent for all three plants. Another striking point

about the data was the uniformity in a given plant of total or suspended solids content of the treated effluent obtained from raw supernatant liquors containing up to about 10,000 p.p.m. of total or suspended solids. For instance, at Cleveland the effluents carried about 350 p.p.m. of suspended solids and about 1,650 p.p.m. of total solids. At Camp Shelby the effluent carried about 360 p.p.m. of suspended solids and about 1,170 p.p.m. of total solids. At Geneva the effluent carried about 200 p.p.m. of suspended solids. Total solids determinations were not made at Geneva.

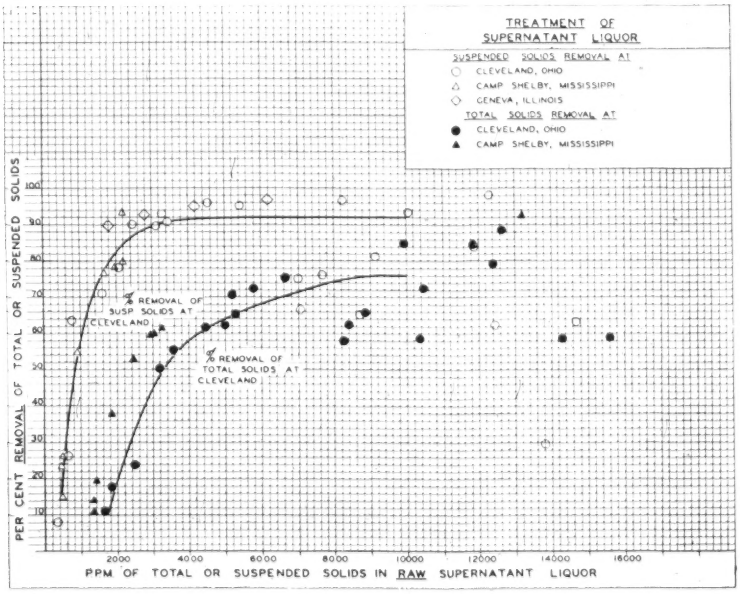

FIG. 1.—Results of supernatant liquor treatment by atomized aeration and settling.

The curves have not been projected for raw supernatant liquor concentrations greater than about 10,000 p.p.m., beyond which a shot-gun pattern of points is shown.

It was definitely determined at Cleveland in certain of the test runs on supernatant liquors having more than 10,000 p.p.m. of total solids, that insufficient volume in the settling tank for the storage of settled solids was permitting deposited solids to be picked up and carried out in the treated effluent, thereby tending to reduce the true percentages of removal.

For this reason, indications are that the removal curves would tend to rise slightly higher for supernatant liquor having solids concentrations greater than 10,000 p.p.m. It is possible that the accumulation

of additional operating data over a wider range of solids concentrations in the raw liquor may permit a more definite differentiation to be made between supernatant liquor and sludge than was possible in the attempt made to define supernatant liquor earlier in this discussion. An experimental unit of somewhat larger proportions than any one of the three units just mentioned is in the process of installation at the Bowery Bay treatment plant in New York City.

In connection with this presentation of operating data, it should be mentioned that, in all three plants, the supernatant liquor treated was drawn directly out of digestion units instead of through the type of selector previously mentioned. A slow continuous draw-off rate, such as that obtainable with the selector, has the effect of bringing the solids concentration of supernatant liquor down into the treatment range, but does not, in itself, constitute a treatment process.

Emphasis should also be given to recognition of the fact that, if digestion has not progressed to a proper stage of completion in a digestion unit, it would be unwise to consider treatment of such supernatant liquor in order to overcome such lack of work done in the digester.

Conclusion

In closing, it is hoped that this presentation has served to emphasize the comparative importance that supernatant liquor may hold in the various problems which confront the designers and operators of sewage treatment plants. It is further hoped that tests and investigations now in progress, or to be undertaken, will lead to improved methods of dealing with the problem.

Discussion

By L. H. Chamberlain

Eastern District Manager, The American Well Works, Aurora, Ill.

There are at least three properties or characteristics of strong digester supernatant liquor that make it difficult to dispose of: its B.O.D., its suspended solids content and its seeding or septifying ability.

The B.O.D. of supernatant seems to manifest itself in a different manner from the usual form of B.O.D. encountered in connection with fresh domestic sewage. That is, in addition to the usual gradual demand for oxygen, this highly anaerobic liquor possesses an immediate demand or avidity for oxygen that requires immediate satisfaction. Such avidity for oxygen is sometimes measured and expressed as a 5-minute B.O.D. and sometimes as a negative dissolved oxygen. Either term refers to the p.p.m. of oxygen required to satisfy the immediate demand for oxygen. Any form of digester supernatant treatment should satisfy this avidity for oxygen and should also cause a reduction in the normal B.O.D.

The suspended solids in the untreated liquor are finely divided and resist separation by sedimentation. A satisfactory method of treatment should increase the settleability of the suspended solids so that they may be dropped out and conveyed back to the digester.

The seeding or septifying tendency of digester supernatant liquor is a characteristic that is receiving increasing thought and attention. Walker and Sperry, in a joint paper presented at the Ohio Sewage Conference in June, 1944, suggested a method of measuring the seeding effect of the liquor by setting up control samples of raw sewage with and without equal additions of treated and untreated supernatant liquor and measuring the methylene blue stability time of each of the samples. Thus, the stability of three samples would be compared: first the raw sewage alone; second, the raw sewage with a definite percentage of untreated supernatant added and third, the raw sewage with the same percentage of treated supernatant added. When, as a result of treatment, the stability of the third sample approaches that of the first, the treatment may be presumed to be very effective. As an example, the following results of laboratory aeration of supernatant are recorded:

Stability of first sample (raw sewage)	$4\frac{3}{4}$ hrs.
Stability of second sample (raw plus untreated supernatant)	1 hr.
Stability of third sample (raw plus treated supernatant—60 min. aeration in beaker)	$4\frac{1}{2}$ hrs.

In cases where the raw sewage is strong and stale and has a stability time close to zero, it is suggested that the effluent of the primary settling tank be used instead of the raw sewage as a control solution.

One type of digester supernatant treatment that has been in use at the activated sludge plant at Bucyrus, Ohio, since 1939 consists of an aeration tank with electrically operated aeration unit and with draw-off piping arranged for the removal of sludge and treated liquor, all as shown in Figure 1.

At Bucyrus a batch of 5,250 gallons of supernatant liquor is aerated for 2 hrs. and then settled for 2 hrs. The thickest sludge is then drawn off to the digester and the clearest liquor is conveyed to the primary settling tank. It has been found beneficial to leave about two feet of liquor and sludge in the tank to seed the next batch. Tests were recently made under the supervision of Mr. Earl Wittner of the Floyd G. Brown Engineering Company and the following results recorded:

	Suspended Solids—P.p.m.			
	3/24/45	3/29/45	4/6/45	Ave.
Raw	4850	2740	3580	3723
Settled 2 hrs.	404	336	304	348
Aerated 2 hrs. and settled 2 hrs.	68	68	76	71

For measuring the seeding or septifying ability of the treated liquor the effluent of the primary settling tank was used as a control. The

primary tank effluent had a methylene blue stability of 165 hrs. Unfortunately, the stability of the control solution plus untreated liquor was not measured but the stability of the control solution plus 10 per cent treated liquor was measured and found to be 110 hrs. It is planned to repeat these tests at Bucyrus, so as to obtain the stability times of all three samples for purposes of comparison.

This type of treatment is also in use at several other sewage treatment plants with equally satisfactory results.

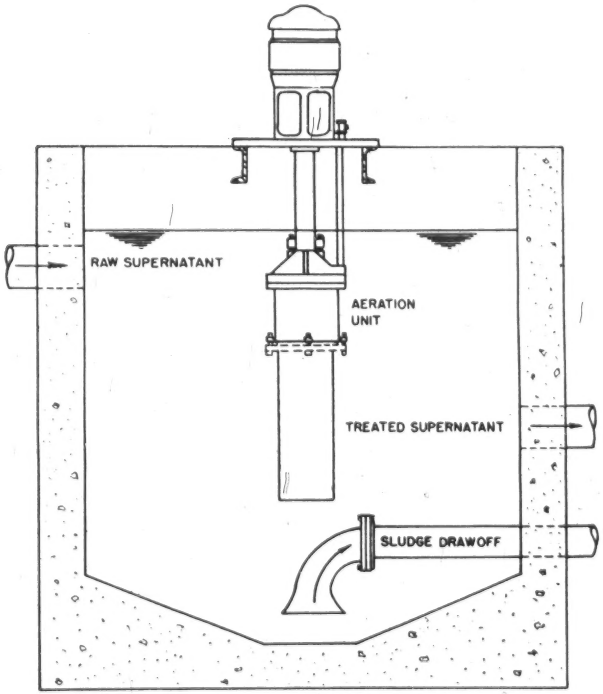

FIG. 1.—Section of supernatant liquor treatment unit at Bucyrus, Ohio.

Another form of treatment consists of the recirculation of a batch of supernatant liquor over a contact filter as shown in Figure 2. The media is anthracite coal passing about ⅜-inch mesh. A blower provides constant ventilation of the bed and the piping is arranged so that the accumulation of solids in the media may be periodically removed by backwashing with water and air. It has been found that the surface of the anthracite media is sufficiently glossy to release the humus almost completely during backwashing, yet there are sufficient voids to cause

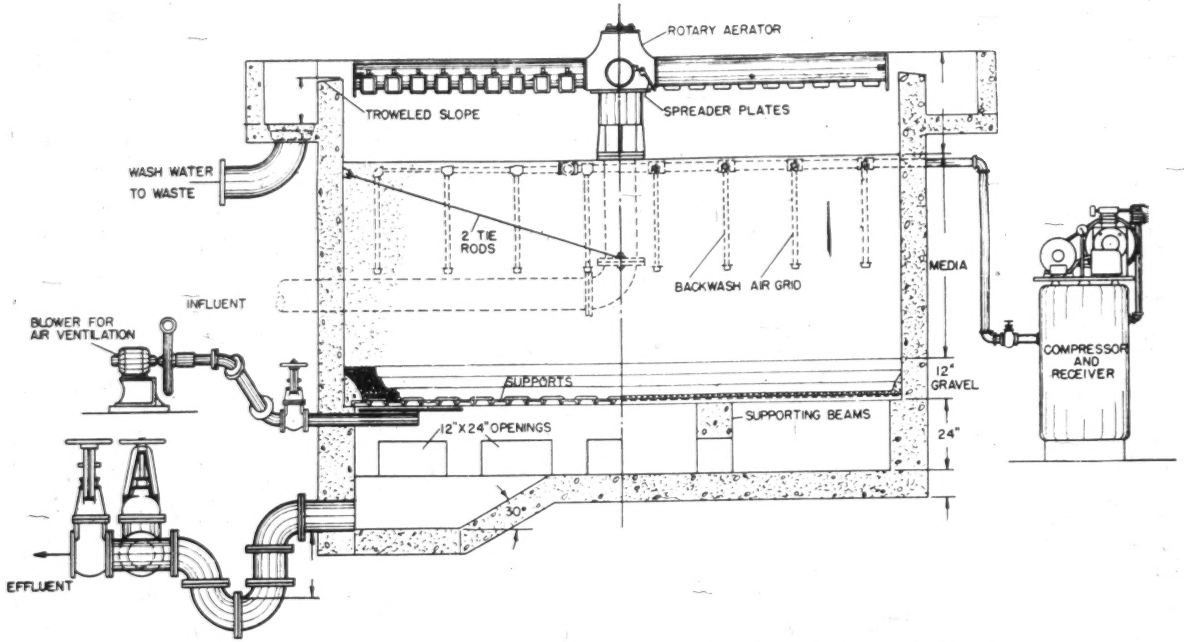

FIG. 2.—Anthracite contact filter with backwash facilities, proposed for treatment of supernatant liquor.

the retention of some humus valuable for seeding purposes. A small pilot plant of this type has been used to treat digester supernatant liquor at Geneva, Illinois, with the following average results during the period October 27 to November 19, 1943:

	Susp. Solids (P.p.m.)	5-Day B.O.D. (P.p.m.)	Dissolved Oxygen (P.p.m.)
Raw	1730	610	0.0
Treated	387	183	4.0

Unfortunately, no records of seeding or septifying ability were made at Geneva.

At the research department of the American Well Works at Aurora, Illinois, supernatant liquor obtained from a digester of the Aurora Sanitary District was treated by this method with satisfactory results. A supernatant liquor having 1,400 p.p.m. 5-day B.O.D. and 20 p.p.m. immediate avidity for oxygen was reduced after 2 hrs. treatment to 185 p.p.m. 5-day B.O.D. and 7.9 p.p.m. dissolved oxygen.

When an attempt was made to use this method of treatment on a very heavy supernatant liquor containing 20,000 p.p.m. suspended solids, the operation was unsatisfactory due to the necessity for frequent backwashing.

In connection with the use of the contact or trickling filter for the treatment of digester supernatant liquor, or for the treatment of strong industrial wastes, it is interesting to note the increase in effectiveness of the filter as the size of media is reduced. Probably this effectiveness is a function of the total surface area of the media so that a study of the surface areas obtainable with various sizes of media should provide a basis for predicting performance. The total surface area of a given volume of closely nested spheres of uniform diameter has been found to vary (for all practical purposes) in inverse proportion to the diameter of the spheres. Thus, a trickling filter using ½-inch media would provide about five times the total surface area of a filter of the same size using 2½-inch media and might be expected to operate with five times the effectiveness. Because of ponding difficulties, the trend for many years has been towards larger media for contact or trickling filters. Where periodic backwashing by means of water and air is not objectionable, small size media may now be used with high loadings and with astonishing results.

Stale sewage and certain industrial wastes possess the same qualities as digester supernatant liquor to a remarkable degree, so that successful types of digester superntant treatment will undoubtedly be found useful for other purposes.

Discussion

By Joseph Doman

Sanitary Engineer, Greenwich Dept. of Public Works, Greenwich, Conn.

The previous speakers have covered in detail the range of problems arising from digester supernatant and have indicated various solutions based upon actual installations and research work still in progress. At Greenwich the problem of handling supernatant arose in 1938 in connection with the remodeling of our disposal plants at Grass Island and Old Greenwich.

At both plants, the sedimentation units were inadequate, Imhoff tanks being used at Grass Island and Septic tanks at Old Greenwich. Rather than add to these units, the designing engineers provided plain settling tanks with sludge removal mechanisms, adequate for the entire flow plus a reasonable future increase, and also provided heated digesters for sludge treatment. The old sedimentation units were used for settling the decanted supernatant but could also be used for storing excess sludge from the digesters if and when this would require further digestion.

Very good effluents are obtained at both plants by settling of the supernatant, the settleable solids in the effluent being usually less than 1 cc. per liter as shown by Imhoff cone tests. A few suspended solids tests showed these to be in the neighborhood of 400 p.p.m., which is approximately twice the strength of average domestic sewage.

At Old Greenwich the settled supernatant is returned to the new settling tanks without deleterious effect, although, during the chlorinating season, it increases the chlorine demand somewhat. At Grass Island the grades are such that pumping would be required to return the settled supernatant to the settling tanks or chlorine contact tank. Rather than install pumps, thus adding to construction and operation costs, the supernatant was discharged by gravity into the effluent outfall sewer. The digester, incidentally, is decanted the first thing in the morning while the clear night flow is still going through the tanks and, during the chlorinating season, the residual chlorine is usually at least 1 p.p.m. The settled supernatant amounts to about 4,000 gal. per m.g. of sewage flow, and this small amount is probably effectively sterilized by the excess chlorine in the sewage effluent before it reaches tide water.

Our general conclusion is that efficient sedimentation of the supernatant has worked out very well at both of these plants.

USE OF CHARTS IN THE ANALYSIS OF SEWAGE TREATMENT PLANT OPERATION *

By W. Vincent Barry

City Engineer, New Haven, Conn.

The skeptic and the novice may say, "Why charts?" It is a vagary of human nature that the mind can best assimilate statistical or numerical data which are graphically represented. If this statement be doubted, one may look about in his daily routine; the local newspaper, the weekly or monthly magazine, the technical publication and promotional pamphlet, all resort to the graphic sketch in their desire to present most efficaciously their pertinent data to their clientele. Whether this be an inheritance from our stone-age ancestors or otherwise, it is, nevertheless, a recognized trait of man's reasoning.

The maintenance of records of the operation of a sewage treatment plant is of fundamental importance. Very often the daily and monthly reports are casually examined, and unless some out-of-line notation is apparent these records are filed away or pigeon-holed. It occurred to the writer early in 1942 that if such records were properly coordinated in a graphical manner, conclusions might be reached which could prove most valuable in attaining the desired objectives, viz., the economical and efficient performance of the disposal plant. Accordingly, the accompanying charts and sketches are presented as examples.

It should be borne in mind that these charts are illustrations of what can be shown and are not intended to be dogmatic. As local conditions vary, charts should be designed in such a manner as to show what is deemed essential for the individual community. Thus, these charts are intended only as models or guides. In obtaining records, accuracy is of the utmost importance. This means accurate sampling, accurate measuring, accurate recording and accurate plotting. Unless accuracy is adhered to, records, charts and reports become meaningless. At this point, it is worthy of mention that "composite" samples are considered to be most representative. Great care must be exercised in the taking of samples.

A close scrutiny of plant records may be used to determine if the character of sewage departs from its normal consistency. If this occurs, the location of the contributing agency affecting the normal operation of a treatment plant may be determined and recommendations adopted to lessen or remove objectional elements. For example, it was found that a chlorine residual in the effluent of one of the New Haven plants could not be maintained during certain periods except by abnormal dosage. By tracing back through the mains, it was ascertained that one of the dye plants was discharging a greatly increased quantity of waste water, containing dye ingredients, into the sewage

* Presented at Spring Meeting of the New England Sewage Works Assn., Boston, Mass., May 2, 1945.

stream. This excess was due principally to an increase in operation of the dye plant from eight hours to twenty-four hours necessitated by war emergency requirements. As this discharge was intermittent and in large quantities, it was determined that by the construction of two storage tanks, the discharge could be made continuous and in smaller quantities so as to minimize the chlorine dosage and thus obtain a satisfactory residual.

By use of charts it is possible to predict within a reasonable degree what quantity of sludge, gas or sludge cake may be obtained within a certain period, which should be of considerable advantage to the operator at critical times. By the use of similar charts, a progressive and over-all picture is visible, and thus operation can be substantiated.

In the operation of a sewage treatment plant, the ideal, viz., the utmost efficiency of every component part, is impossible of attainment. What then should be considered as satisfactory performance? As this paper is a review of actual experience, the writer must confine himself to primary treatment only. The main factors in this type of treatment at New Haven are:

1. Removal of suspended solids.
2. (a) Digestion; if sewage is not sterile, or
   (b) Temporary storage to render sludge more gelatinous or thickened.
3. Chemical treatment prior to vacuum filtration.
4. Incineration.
5. Removal or use of ashes.

Reviewing these steps, it would seem that the highest percentage of solids removal should be the aim, but as the detention period is one of the main factors in this reduction, a detention period beyond an efficient removal is undesirable. For instance, more suspended solids can be removed from sewage in a 4-hour period than in a 2-hour period. But more solids are removed in the first thirty minutes than in the last thirty. As detention period is governed by capacity of settling tanks, detention beyond an efficient period would be uneconomical, as larger tanks occupying more area and containing additional mechanical equipment would be required. This would exact a greater initial investment and also increase the operating and maintenance costs. Therefore, the removal of such quantity of solids as is compatible with the designed detention should be maintained. At the plant using incineration (where no digesters are present), it can be observed that the higher the percentage of dry solids in the sludge removed from the thickening tanks, the smaller the percentage of chemical agents required to produce conditioning of sludge.

As use of these chemicals, particularly ferric chloride, constitutes a large proportion of the cost, their addition should be held to a minimum. Thus, it is necessary to determine from experience an efficient relationship between length of settlement and amount of chemicals. In a plant using incineration after digestion, it is equally true that the

amount of chemicals to be added to digested sludge is governed by the amount of dry solids therein. Therefore, in most plants, sludge should be thoroughly digested for the economical conditioning mentioned above.

Proceeding to the preparation of digested sludge or undigested (raw) sludge for filtration, utmost care must be exercised in the laboratory for the determination of the amount of chemicals to be added.

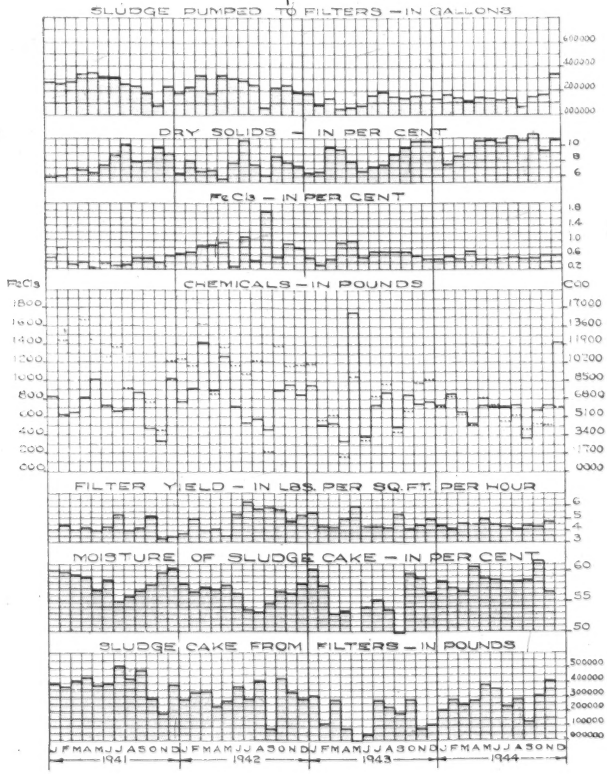

Fig. 1.—Chart of sludge conditioning and dewatering data at East Street sewage treatment plant, New Haven, Conn.

If, in addition to ferric chloride, lime is to be added as a thickener, the proper quantitative ratio between these two should be determined to the end that an economical relationship be established. That there can be and is a wide divergence in the proportion is evidenced in Figures 1 and 2; the ratio at the East Street plant being 1 pound of ferric chloride to 8½ pounds of lime (CaO) and at the Boulevard plant the ratio is 1 to 4, similarly.

Filter cake yield also has an important bearing in the efficient operation of the plant. A yield of four pounds per square foot per hour is considered satisfactory. It should be borne in mind that too much reduction in moisture content of the cake is uneconomical, as the incinerator is designed to burn sludge cake of an established moisture content,

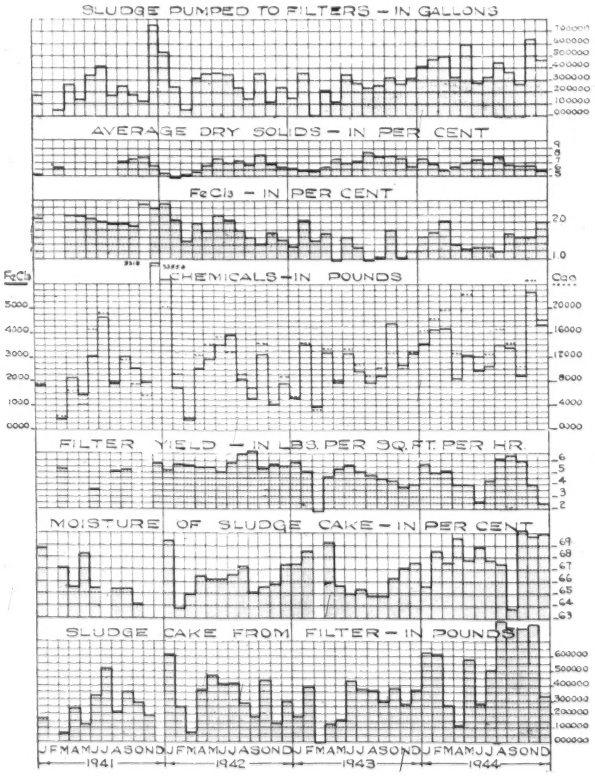
SLUDGE PUMPED TO FILTERS – IN GALLONS
AVERAGE DRY SOLIDS – IN PER CENT
FeCl3 – IN PER CENT
CHEMICALS – IN POUNDS
FeCl3
CaO
FILTER YIELD – IN LBS. PER SQ. FT. PER HR.
MOISTURE OF SLUDGE CAKE – IN PER CENT
SLUDGE CAKE FROM FILTER – IN POUNDS
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1941
1942
1943
1944

FIG. 2.—Chart of sludge conditioning and dewatering data at Boulevard sewage treatment plant, New Haven Conn.

and too much deviation from this value will result in inefficient consumption or uneconomical usage of chemicals.

For example, if the designed operating efficiency of an incinerator is cremation of sludge cake having a moisture content of seventy per cent, then attempts should be made to approximate this figure. Less moisture content means that the optimum amounts of conditioning chemicals have been exceeded, which naturally results in increasing the

cost of conditioning sludge cake. On the other side, greater moisture content than seventy per cent means excesses in quantity of fuel oil in the upper hearths of the furnace, thus increasing cost of incineration.

In the preparation of charts, it is the writer's belief that interdependent records should be plotted on one sheet insofar as practicable. For instance, percentage of suspended solids removed, time of deten-

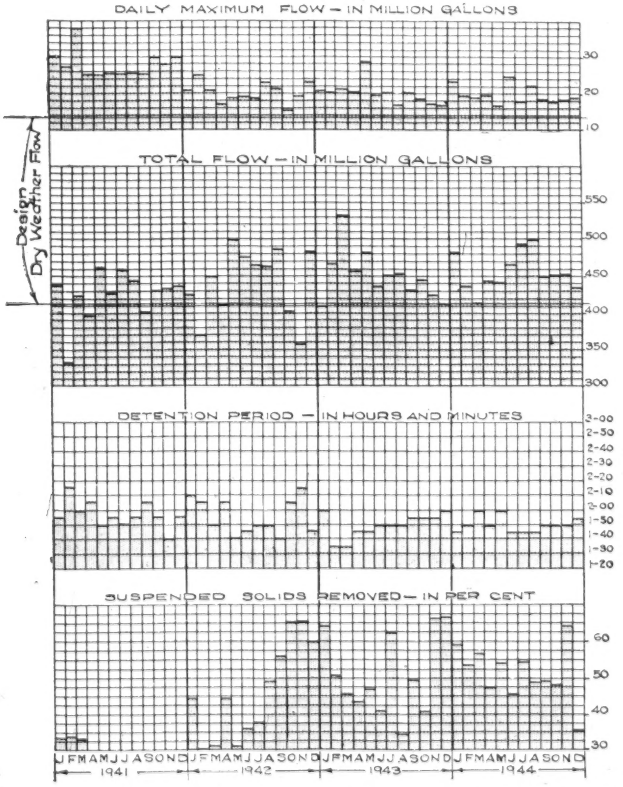

FIG. 3.—Sewage flow and sedimentation chart, Boulevard plant, New Haven, Conn.

tion, total sewage flow and maximum daily flow are closely allied, and thus should be recorded on the same page (Figure 3). On another sheet (Figure 2), total sludge (either digested or "raw") to be conditioned is shown together with percentage of dry solids therein, total amounts of chemicals added and percentage of ferric chloride. In addition, filter yield and percentage of moisture of sludge cake are included as is the total amount of sludge cake.

Plant	Year	Type	Raw M.G.	Screenings Cu. Ft.	Grit Cu. Ft.	Raw Sludge Gals.	Sludge to Filters Gals.	Sludge Digested Gals.	Sludge Digested Lbs.	Sludge Gas to Tanks Cu. Ft.	Gas Thousand Cu. Ft.	Hours Operated	Power Thousand K.W.H.	FeCl3 Lbs.	Cao Lbs.	Ash Lbs.	Oil Gals.	Total Cost	Cost Per M.G.
EAST ST.	1941	SI	3130	17629	12090	19761270	3192701	4706429				2260	135	8795	123527		1193	36051	11.52
EAST ST.	1942	SI	3527	17997	11042	25695462	2769875	3765286				2084	134	10,283	115274		1326	42814	11.97
EAST ST.	1943	SI	3411	21670	13783	23430190	1584000	2050561				1144	112	8975	78194		821	43454	12.73
EAST ST.	1944	SI	3655	14882	12404	22931120	1771677	2781849				1534	123	8955	64993		1394	45198	1240
BOULEVARD	1941	SDI	3685	3933	15971	6444678	2903615	3514728			19154	1499	854	32392	120739		3164	44205	8.72
BOULEVARD	1942	SDI	5295	3166	13430	6610914	3922089	3895238			19315	1421	872	31923	129641		6916	49044	9.28
BOULEVARD	1943	SDI	5413	3737	13143	5643200	2817004	3350420	2870000		16532	1490	858	30581	123382		3268	48479	8.93
BOULEVARD	1944	SDI	5475	3614	17358	5420800	5021139	6703691	4550000		18996	2706	894	41280	198239		4196	53275	9.75

S = Plain Sedimentation. D = Digestion. I = Incineration.

FIG. 4.—Annual operation statistics at New Haven sewage treatment plants.

In the plotting of amounts of chemicals applied, the graduations used should be designed so as to show the established operating ratio. On one side of this scale, the values indicated are multiple components of those on the opposite side, as derived from operation. As an illustration, in Figure 2 showing the pounds of chemicals used, the gradu-

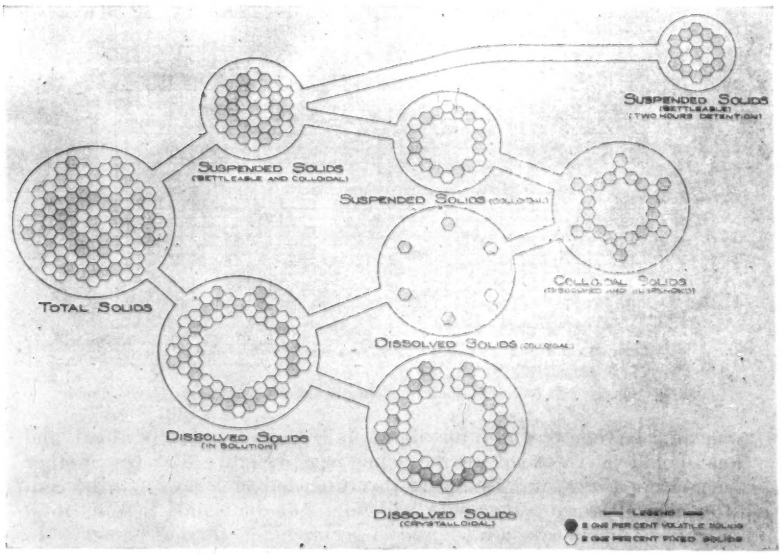

FIG. 5.—Graphical representation of the distribution of the principal solid constituents of a sewage of medium strength.

ations on the right side have a numerical value of four times those on the left. Thus, in plotting quantities of chemicals used in any period, the observer can tell at a glance whether or not the proper ratio was in use in conditioning and if not, the chemical used in excess is very much in evidence. Close attention to this chart can result in economy with respect to chemicals applied.

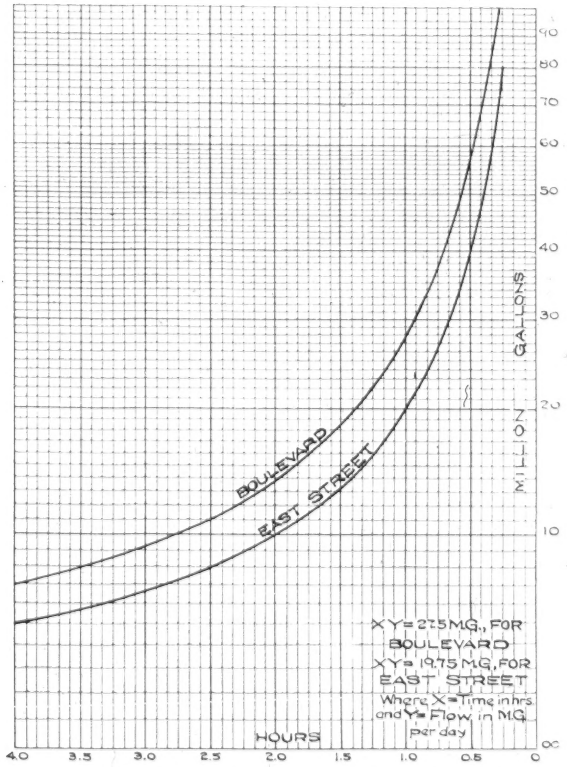

FIG. 6.—Primary sedimentation tank detention period chart.

These charts are particularly significant in that they show statistics from the very start of operation of the plants; Boulevard plant was placed in operation late in 1940 and East Street plant early in 1941. Thus it can be seen how erratic performance has been levelled off, and a more regular routine developed. In the plotting of these charts, a 4-year record was established for just this reason. For the continuous record, a charting period of three years would seem to be the minimum desideratum.

Irrespective of the adopted term of years, the recorded performance of the year previous should be plotted as this will afford a comparative medium to determine monthly efficiency. Any great divergence may thus be noted, and by reference to previous years such variance may be reconciled. Where a number of years are plotted on a single sheet (Figure 4), comparative figures for a designated month in each year may be more readily ascertained by the use of a template. By application of this template to the record sheet, the figures for the desired month in each year will alone be visible.

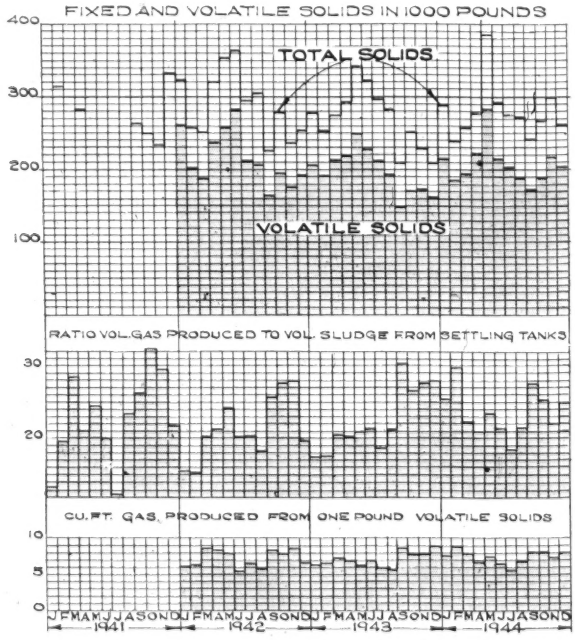
FIXED AND VOLATILE SOLIDS IN 1000 POUNDS
400
300
200
100
TOTAL SOLIDS
VOLATILE SOLIDS
RATIO VOL. GAS PRODUCED TO VOL. SLUDGE FROM SETTLING TANKS
30
20
CU. FT. GAS PRODUCED FROM ONE POUND VOLATILE SOLIDS
10
5
0
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1941
1942
1943
1944

FIG. 7.—Chart showing fixed and volatile solids in thousand pounds, Boulevard plant, New Haven, Conn.

Figure 4 is mute evidence of the fallacy of the use of "cost per million gallons" as the sole measure of plant efficiency. While there is much less annual consumption of power at East Street and somewhat lower use of chemicals, the unit cost is greater than at the Boulevard plant. On the surface this would seem inconsistent, particularly as there is less mechanical equipment at the East Street plant. More manual operation is required, however, at East Street and eleven men are employed there, and while the same number of employees are in attendance at Boulevard, the latter could be considered as under-

manned. This is due mainly to the manpower shortage of the present era. Thus, while the payroll is nearly equal at both plants, the total yearly flow at Boulevard is fifty per cent greater than at East Street and accounts in a large measure for the smaller cost per million gallons of sewage treated. Consequently, in the design of plants, other factors should be investigated.

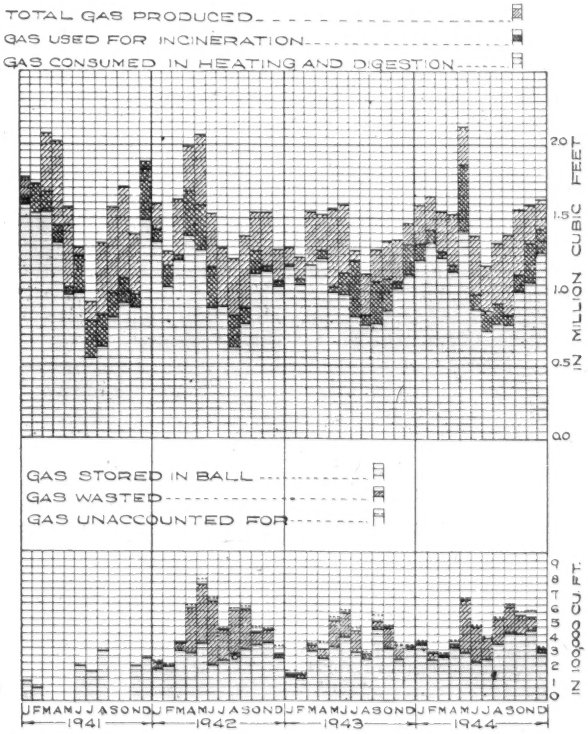
TOTAL GAS PRODUCED
GAS USED FOR INCINERATION
GAS CONSUMED IN HEATING AND DIGESTION
2.0
1.5
1.0
0.5
0.0
MILLION CUBIC FEET
GAS STORED IN BALL
GAS WASTED
GAS UNACCOUNTED FOR
100,000 CU. FT.
J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D J F M A M J J A S O N D
1941
1942
1943
1944

FIG. 8.—Gas utilization chart, Boulevard plant, New Haven, Conn.

Figure 5, showing the composition in per cent of the various types of solids in sewage, is an attempt by the writer to represent in a graphical manner the literal definition of the same according to Metcalf and Eddy. This chart shows at a glance the physical composition of solids in medium strength sewage (800 p.p.m.) and such removal as may be accomplished in a 2-hour detention period. Removal might be augmented by flocculation, mechanical or chemical. This sketch also shows that while the amount of solids which can be removed is not great in the final analysis, the percentage of removal may loom large. In the

groupings on this chart, the relative position of the various classifications of solids has been maintained so as to portray their actual proportions. Many of the dissolved solids are brought into the sewage by the carrying medium, viz., the water. This chart has a particular value in sanitation courses, as the student should be able to visualize more rapidly the distribution of solids in sewage.

Flow diagrams of the New Haven plants have been prepared for convenience of plant employees. Instead of lines and notations, mechanical equipment is shown in its approximate outline and location. This makes each operation more understandable to the operator and should envision equipment and its function more clearly to the uninitiated.

By use of colors, the various removals or changes can be more readily brought out. For instance, if the influent is colored blue with brown dashes scattered throughout, then in the sedimentation tanks, by showing a solid brown color at the lower level and tinting the upper level in blue, the settling out of the solids can be clearly demonstrated.

Figures 6, 7 and 8 illustrate other charts used to advantage in picturing operation data gathered in the New Haven sewage treatment plants. Each one condenses a long story into limited space.

In general, remembering the key word "accuracy," charts will show the overall operating accomplishment. A close study by the operator can result in the reasonable attainment of that ever elusive Utopia of plant operation—maximum efficiency.

INSTALLATION AND MAINTENANCE OF SEWER CONNECTIONS *

By Nicol MacNicol

Commissioner of Works, Village of Forest Hill, Ont., Canada

With many other problems confronting the municipal engineer there is perhaps an inclination to consider the installation and maintenance of sewer connections a routine matter of minor importance. As long as a sewer functions properly it is unseen and unheeded, but when failure occurs we are immediately reminded that this is one of the basic conveniences of urban life. In the sanitary field engineers have been devoting most of their time to the treatment and disposal of sewage, sometimes forgetting that the disposal problem begins at the house or industrial connection. As this connection is the only part with which the average citizen becomes acquainted, the efficiency of the whole system will be generally appraised by its dependability. It is one sanitary facility, the design and construction of which is left largely to the so-called practical drain layer, and to which too little technical supervision is given.

It may, therefore, be profitable to review significant points in regard to this subject. Information will be partly from the practice followed in the village of Forest Hill, and partly from that of other municipalities. Some of the data are taken from the answers of 78 municipalities to a recent questionnaire, issued by the Canadian Institute on Sewage and Sanitation.

Installation

Procedure and Responsibility

In most Canadian municipalities it is regular practice for the street portion of a sewer connection to be paid for by the property owner, and installed by the municipality, after which the balance of the connection is laid by the owner's contractor under municipal inspection. Charges for the street portion vary with the locality, width of street, whether paved, etc.

In about 25 per cent of cases, the municipality does not do any part of the work, which is usually performed for the owner by a bonded contractor. This system applies in such cities as Saint John, Halifax, Montreal, Ottawa, Kingston, Hamilton, Niagara Falls, Galt, Brandon, Windsor, Sault Ste. Marie and Winnipeg, and has the obvious advantage that if subsequent trouble develops on any part of the connection there can be no suggestion that this is the responsibility of the municipality. Further reference will be made to responsibility for blockages under the heading of maintenance.

* A special contribution originally intended for presentation in the technical program of the Eighteenth Annual Meeting and Sixth Annual Convention of the Federation, since postponed.

Excavation

The width of trench to be dug will, of course, depend on the size and number of pipes being laid, and the necessity for sheeting. Sufficient width must be allowed for the proper making of joints, and the bottom of the trench recessed to fit the collar of the pipe, not only for good bearing, but to allow for an equal annular space between bell and spigot for the placing of a jointing material.

Where a pavement has to be "opened" it is important to make the cut as small as conveniently possible, to reduce the cost of repairs to a minimum. For ordinary purposes a cut two feet wide by six feet long should be sufficient.

Pipe

Most municipalities use first quality glazed collar tile, although there are a few cases where concrete pipe has been adopted. For separate sewers four- and six-inch pipe are both employed, while all use not less than six-inch pipe for combined systems. A number of cities such as Vancouver, Winnipeg, London, Ottawa, Windsor, Kitchener, Guelph and Stratford specify cast iron pipe under basement floors, and to a point three to eight feet outside the basement wall. It is sometimes suggested that connections should be cast iron throughout, but this would increase costs considerably, particularly for separate systems, and would not materially lessen the possibility of blockage from within. There is also a pipe made of asphalt compound, with sleeve-like joints which are driven tightly together, but it has not been used long enough locally to determine whether this type of joint is root-proof.

Laying and Jointing

As tree roots and internal roughness of joints are common causes of blockages, the importance of good materials and workmanship needs no elaboration. A tree root finer than human hair reaching for moisture will find its way through a fine crack in a cement joint or a blowhole or crack in a bitumen joint. Whatever material is used, it is essential to prevent formation of cracks through shrinkage, or movement of the pipe after the joint has been made.

Almost all municipalities use a cement joint, either a mixture of sand and cement in the ratio of one or two to one, or neat cement. Very few are using the asphalt compound, and some who have tried it say a properly made cement joint is just as good and less trouble. In fitting pipes together use of stranded oakum is recommended to provide an equal annular space and to prevent the jointing mixture from getting on the inside of the pipe.

In F. C. Palmer's paper entitled "Laying and Jointing Sewer Pipes," to be published in *Water Works and Sewerage*, detailed reference is made to various kinds of patented joints, and to use of asphalt compound or cement for same. He recommends an asphalt strip pre-

formed to fit the annual space in the joint. After caulking this into place the balance of the annular space is filled with cement mortar. This provides a water and root-proof joint. Mr. Palmer also describes in detail how the best cement joint should be made. "One part portland cement, two and one-half parts clean sharp sand, mix dry, then add sufficient water to dampen, then mix. Allow to stand for forty-five minutes, then add sufficient water to bring to the consistency for good trowelling. This mix and the time allowed to pre-hydrate with moisture, eliminates shrinkage, and gives excellent adhesion."

Conceding that shrinkage in a joint made of sand and cement in the manner specified would be less than for neat cement, we in Forest Hill have nevertheless specified the latter, because of the impracticability of checking the accuracy of any mixture of cement and sand used by private contractors. We have found that a quick strength cement such as "XXX," made by the Canada Cement Co. is more plastic, less porous, less subject to shrinkage than standard "Portland" cement, and costs less than one cent per foot more. Allowance for pre-hydration, as recommended above, should be made regardless of the mix.

Before wartime restrictions on certain metals were imposed a few municipalities had standardized on use of copper rings with cement mortar joints, and others used them in rejointing a drain which had been blocked with roots.

The important points in the foregoing may be summarized briefly as follows:

(1) Provide sufficient width of trench for proper workmanship.
(2) Use jute or oakum around portion of pipe barrel entering socket. (In hot weather spigot and socket should be wetted.)
(3) Prevent hair-cracking of jointing material, due to shrinkage, or movement of pipe while joint material is setting.

Where either four- or six-inch pipes are used it is customary to use a minimum grade of one-quarter inch per foot. Storm water drains can be laid on a slightly flatter grade than those carrying sanitary sewage only, but in either case it is, of course, preferable to have and use more than the minimum requirement.

Opinions vary regarding the proximity of sewer and water connections. While most municipalities apparently do not object to these two services being laid in a common trench, it certainly seems preferable to have them separated three feet or more, so that there is no danger of damaging one if repairing the other.

Backfilling and Consolidating

To prevent disturbance of newly made joints, backfilling should be postponed until after initial set, and then done with sufficient care to avoid cracking joints. To avoid piling extra material on a street, speed up work and save expense, it is, however, regular practice to place material being excavated over pipes freshly laid. While this method also has the advantage of protecting setting mortar from summer heat, there

is no doubt that joints are sometimes broken, through which tree roots may subsequently enter.

From a point approximately three feet above the level of the pipe, backfilling should be consolidated at one or two foot intervals by tamping. The following day when the joints have taken their initial set, and if the soil is suitable, further consolidation should be made with water forced into the refilled trench with a half-inch pipe about six feet long.

Roadway Repairs

On a paved street when the trench has been consolidated, if it is not possible to make permanent repairs immediately, a good arrangement is to apply a mixture of fine stone and asphalt. This binds the surface of the roadway, waterproofs the cut and makes a satisfactory temporary repair until permanent repaving can be done. At that time, after removing the temporary surface the trench should again be consolidated with water, in this way making sure that there will not be subsequent settlement to leave a hollow space under the pavement.

Cost Keeping and Records

When an application for installation of a sewer connection is received and paid for, a work order is issued to the foreman, giving necessary particulars and providing space to show the location of the completed work and the time and material used. After the work order has been returned to the office the location of the connection should be transferred to street plan records. Weekly checks and monthly summaries should be made to determine whether work has been done at a profit or loss, and this information promptly reported to the foreman or superintendent.

Drains on Private Property

Members of the Canadian Institute on Sewage and Sanitation who have attended annual conventions will remember discussions for and against installation of main traps and breathers. The contention is that where each fixture is properly trapped and vented there is no need for a main trap and breather, and that such a trap when installed is a common cause of blockage, difficult to clear without digging. Approximately three-quarters of municipalities reporting do not install either a main trap or breather, and of the balance about one-half install them inside the front basement wall, rather than at the street line. Obviously there would be fewer blockages where there is no main trap, but answers surprisingly showed that percentages cleared without digging were almost as favorable under one condition as the other.

In Forest Hill where the main trap and breather are installed at the street line, with 2,650 drains in service, the average number of blockages per year is 2.6 per cent, and of these three-quarters are cleared without digging. There is, however, so much variation in conditions in different municipalities that quoting of figures does not prove much. It

does seem, however, that with the exception of grease, any object which will pass a trapped fixture in a building should be able to pass a main trap without having to dig up the service. There have been cases of explosions in sewers where buildings with untrapped connections have had fixtures blown off the walls.

The city of Winnipeg considers that wherever climatic conditions cause closure of the soil and vent pipe terminal by frost, a main trap should be installed to prevent main sewer gases from entering the building. Placing the trap under the basement floor at the front wall of the building gives protection from gases, and provides reasonable accessibility; where installations are made in this way, the breather pipe is extended through the basement wall eighteen inches above the ground line.

To assist in clearing blockages it is standard practice to install a cleanout fitting at the base of each stack and one inside the front wall on the storm drain.

Municipal Plumbing By-Law and Inspection

The result of the survey by the Institute in May, 1941, showed that 34 out of 89 municipalities then reporting had no local by-law regulating plumbing and installation of drains. As some provinces have no minimum plumbing code, a standard Plumbing By-Law was prepared and published in 1941 under the joint sponsorship of the National Housing Administration and the National Research Council of Canada.

The importance of thorough inspection of drain-work done by private contractors is too obvious to need special emphasis. Drain layers are licensed in Forest Hill, and in a number of other Canadian municipalities. Each installation requires a municipal permit, and has to pass a ball test; every second length of pipe is checked for grade, and the inspector reports measurements taken, etc., on a special form.

In some municipalities plumbing inspection is under the supervision of the Medical Officer of Health, while in others this is done under the Engineering Department. Opinion is divided as to which is the better arrangement. The wide powers given the Medical Officer under the Public Health Act are certainly useful in some cases, but where the municipality employs an engineer it would seem logical to assume that he would have more knowledge of the details of plumbing construction and could always request the cooperation of the Medical Officer, when necessary.

Maintenance

Blockages

In dealing with the installation of sewer connections most, if not all, maintenance problems and remedies have already been indicated. There are cases of bad workmanship, insufficient grade or carelessness and misuse on the part of the occupant of a building, such as permitting grease to get into a drain and form a hard lump, but the most common

trouble, and the most difficult to cure is, of course, tree roots. Where a trench is cut through hard ground, roots of trees sometimes 25 feet (or more) away will follow the back-fill and seek the tiniest opening in a pipe to obtain moisture. The use of good materials and workmanship in the original installation has already been dealt with, but what are the remedies when blockage has occurred?

Responsibility and Repairs

Where there is a main trap and breather, it is customary first to try plunging the breather, and in some cases if the connection seems dirty, also to flush through the same. In Forest Hill a charge of $1.50 is made for plunging, and an additional $1.50 for flushing. If this does not clear the drain, the householder is notified that digging will be necessary and that if the municipality is to do this work a deposit of $25 must be made.

Digging is first done at the street line, the pipe opened and the blockage located. If the blockage is on private property, or due to misuse of connection, or if roots have entered the drain on private property, the cost of repairs is charged to the householder. If roots have entered on both private and public property the cost is divided; if all on the street, there is no charge to the householder.

Other municipalities vary this procedure. Where the connection has been wholly installed by the property owner or his contractor there is, of course, no responsibility to be assumed by the municipality. In other cases repairs to the street portion are assumed by the owner, shared equally between the two parties, or paid wholly by the municipality—usually the latter. Where it is customary for the municipality to assume the cost of any repairs on the street, a property owner sometimes questions a charge for a blockage on private property, if caused by roots of a tree located on the street. The courts have, however, ruled that such a tree belongs to the owner of the property in front of which it is located, and therefore no claim can be made for damage caused by its roots.

Where a main trap has not been installed it will be possible to clear roots without digging, but this can only be regarded as a temporary measure. Householders are sometimes advised to use copper sulphate periodically to kill roots, but they grow so rapidly that re-laying all or part of the drain is considered the most permanent cure. If roots have entered at only one or two places these joints can be remade and encased with extra concrete, or copper root-rings can be installed with the new joints. The most permanent job is to re-lay the drain with cast iron pipe and lead joints.

The cause of most trouble locally is willows, poplars, manitoba and silver maples, and elms—all fast-growing varieties of trees. Municipal control of tree-planting is, therefore, essential. In Forest Hill it has been found that trees planted ten to twenty years ago at 25- to 30-foot centers are now too close together, and that removal of alternate trees improves street appearance, as well as lessening sewer and water system troubles.

Flexible steel rods and machine operated cutters are useful in locating and clearing blockages quickly with a minimum amount of digging, but where roots are the trouble, the question of whether to clear with these tools or to re-lay the drain becomes one of comparative costs.

Legal Cases

Two cases illustrating responsibility for sewer blockages may be briefly summarized as follows:

(1) *Siegel vs City of Hamilton*—First Division Court, County of Wentworth, July, 1938. The claim was for $71.40, being the cost of removing tree roots from a sewer connection on the plaintiff's premises. The evidence indicated that roots from a soft maple tree located on the street had entered the plaintiff's lands and obstructed his sewer.

Judge Schwenger referred to section 511, sub-section 3 of the Ontario Municipal Act, and ruled that the plaintiff had a proprietary interest in the tree in question and, therefore, could not refuse to accept responsibility for same. The action was dismissed with costs.

(2) *Stockinger vs Town of Cobourg*—Ontario High Court, June, 1943. Judge Kelly ruled that the owner of property, the drain of which was connected with a municipal sewer as a matter of permission, and not by virtue of any legal obligation, had no cause of action against the municipality when his basement became flooded owing to the blocking of the drain by the roots of a tree on the adjacent highway. The property owner had a proprietary interest in the tree and hence no obligation to repair the drain rested on the municipality. The action was dismissed with costs.

Basement Flooding

This may be due to an overloaded main sewer, unusually heavy rainfall, insufficient difference in level between basement floor and main sewer, or a blockage in a sewer connection. If the connection cannot be improved and the condition is likely to recur, floor washouts should be sealed off, a back-pressure valve installed, or screw-cap fittings placed in floor-wash outlets, the best solution depending on local conditions. With a separate system in Forest Hill, we have found that bronze screw-cap fittings were easily installed, and were fool proof, provided that the householder kept them closed except when in use.

Conclusion

To many of those responsible for the installation and maintenance of sewer connections, the foregoing will contain little that is new. It is hoped, however, that this general summary of Canadian practice will cause officials to review their local problems, and that further discussion may be promoted which will add to the general knowledge of the subject.

A USEFUL TECHNIC IN GROUND WATER INFILTRATION STUDIES

By Charles A. McLoughlin, C.E.

Passed Asst. Engineer (R), U. S. Public Health Service

A system of approximately 3.5 miles of 8- and 10-inch vitrified tile gravity sanitary sewers has been constructed to serve two war housing projects in a southern Connecticut town. These sewers discharge to a common 10-inch vitrified tile line to a pumping station (Figure 1), from which the sewage is raised to the town sewage treatment plant. Upon completion of the system and before occupancy of the projects, the town objected to placing the pumping station in operation. It was contended that ground water infiltration was excessive and would aggravate conditions at the already overloaded treatment plant.

A study of the contract specifications revealed that no infiltration limit had been set. The standard specifications established a maximum infiltration rate of 10,000 gallons per day per mile of sewer regardless of diameter. It appears that some consideration should be given to the size of pipe used. A more commonly used criterion which takes this factor into consideration is usually stated as follows: "Ground water infiltration shall not exceed one gallon per hour per inch diameter per 100 feet of sewer." This latter criterion establishes an infiltration limit of 10,140 gallons for 8-inch and 12,670 gallons for 10-inch sewers per mile per day. The town officials alleged that this limit was considerably exceeded and, if secured, would be acceptable.

The sewers were constructed of vitrified clay bell and spigot pipe with poured bitumastic joints. A considerable amount of ground water was encountered during construction, particularly in the off-site or outfall sewer between Manhole No. 5 and Manhole No. 0. There is a constant head of ground water of from 4 to 6 feet over the 480-foot length of pipe between Manhole No. 2 and Manhole No. 0. The material encountered in excavation closely resembled quicksand. In spite of these conditions no special precautions were prescribed in the specifications for laying the sewer in this section, and no extraordinary care was taken by the contractor other than pumping the excavation nearly dry during the pipe-laying operation.

In making the investigation reported here, it was first determined that none of the dwelling units in these projects was occupied; the water supply to the units was shut off at the meter pits. Tests were made at various points in the water distribution systems to be certain that none of the supply would reach the sewers and that the only flow in the sewers would, therefore, be due to ground water infiltration.

In order to determine the flow, tests were made at Manhole No. 0 over the wet well of the pumping station. A portable, gasoline motor-driven diaphragm pump was set up with the suction intake in the well. The speed of the pump was regulated so that the water level in the well

remained constant, and pumpage was equivalent to the flow into the well. A 55-gallon steel drum was set up and filled by the pump discharge and the time required to fill it was carefully noted. This operation was repeated three times, and the average time required to fill the drum was 51 seconds. This is equivalent to a flow of 93,312 gallons per day, which amounts to an infiltration rate of 26,600 gallons per day

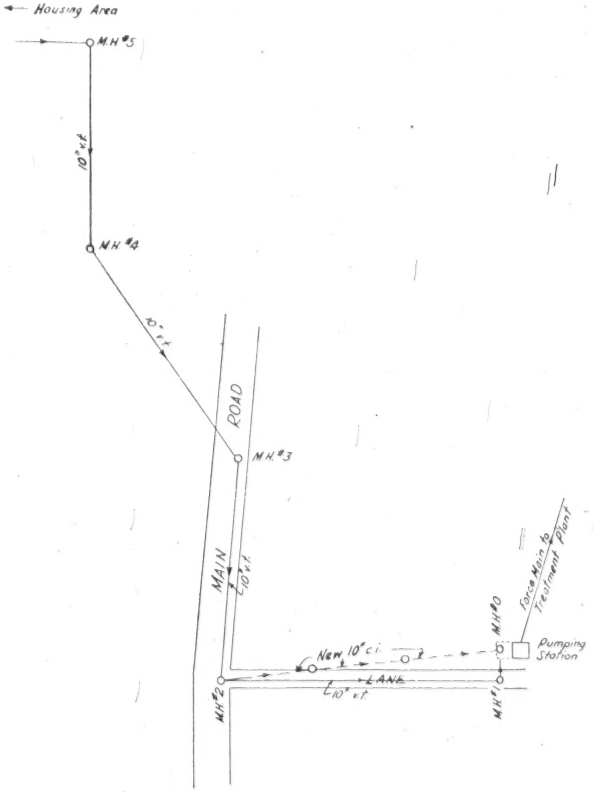

FIG. 1.—Off site sanitary sewer from housing area to pumping station.

per mile of sewer. On the basis of the criteria hereinbefore discussed, this rate of infiltration is more than twice that usually permitted.

An efficient stopper was made (Figure 2) and used to plug the upstream 10-inch pipe in Manhole No. 5. The flow then entering the wet well was solely infiltration into the off-site sewer from Manhole No. 5 to Manhole No. 0, a distance of approximately 1,500 feet. Using the procedure outlined in the foregoing paragraph, the 55-gallon drum was

filled and emptied four times and the average time of filling determined at 81 seconds. This is equivalent to a rate of 0.68 gals. per second; or 58,752 g.p.d.; or 207,000 g.p.d. per mile of sewer.

By deducting the flow determined for the off-site sewer (58,752 g.p.d.) from that in the entire system (93,312 g.p.d.), infiltration into the on-site sewers was established at 34,560 g.p.d., or at a rate of approximately 10,740 g.p.d. per mile of pipe. This rate of infiltration is within the usual requirements for a system composed of 10-inch and 8-inch sewers.

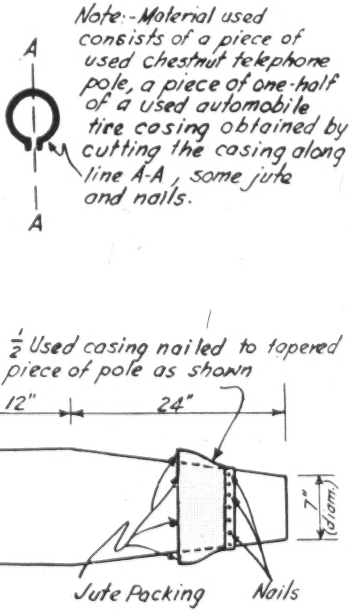
Note:-Material used consists of a piece of used chestnut telephone pole, a piece of one-half of a used automobile tire casing obtained by cutting the casing along line A-A, some jute and nails.
A
A
½ Used casing nailed to tapered piece of pole as shown
12"
24"
12" (diam.)
7" (diam.)
Jute Packing
Nails

FIG. 2.—Detail of sewer plug used in making infiltration studies.

It was evident from these tests that most of the infiltration to the system was occurring in the off-site sewers from Manhole No. 5 to the pumping station, a distance of approximately 1,500 feet. Tests were undertaken to localize this condition more definitely. A stopper was inserted in the influent sewer at Manhole No. 2 and further flow tests at the wet well revealed a flow for the 480 feet of pipe from Manhole No. 2 to Manhole No. 0 of 50,112 g.p.d. or an infiltration rate of some 506,800 g.p.d. per mile of sewer. Deducting the flow of 50,112 g.p.d. from the flow previously determined for the sewer between Manhole No. 5 to Manhole No. 0 of 58,752 g.p.d., a flow of 8,640 g.p.d. is obtained for that stretch of sewer between Manhole No. 5 and Manhole No. 2. This is

equivalent to an infiltration rate of 44,700 g.p.d. per mile of sewer, or 3 to 4 times that which would be permitted by the town.

From a study of the quantities of flow obtained for the entire system and its component parts it was evident that, to obtain an infiltration rate for the entire system that would be acceptable to the town, it would be necessary to overcome nearly all of the infiltration to the 10-inch sewer between Manhole No. 2 and Manhole No. 0. If infiltration could be entirely eliminated in this sewer, the resultant infiltration rate for the entire system of sewers would be reduced to 12,300 g.p.d. per mile of sewer.

The influent 10-inch sewer to Manhole No. 1 was plugged and the flow into the wet well was negligible, indicating that infiltration in this short line could be disregarded.

It was necessary to devise some means of determining the cause of the excessive infiltration of ground water to the sewer between Manhole No. 2 and Manhole No. 1, so that the most effective corrective measures could be prescribed. Leakage could possibly be due to one or several breaks in the line, or to uniform leakage through the pipe joints. It was decided that if a watertight plug could be installed in the 10-inch sewer, starting at Manhole No. 2, and moved in successive stages toward Manhole No. 1 with flow measurements being taken at each stage, the existence of any major breaks would be detected and located.

A standard pear-shaped punching bag was purchased at a local sporting goods store; the maximum diameter of the bag was 10 inches. By opening some of the stitched seams in the cover and overinflating the bag slightly, a tight fit in a 10-inch pipe was obtained. Three hundred feet of strong sash cord was supplied by the contractor. The end of a ball of mason's line was tied to a small block of wood and the block floated through the sewer from Manhole No. 2 to Manhole No. 1, as the line was paid out. Then the sash cord was tied to the line and drawn through the sewer to Manhole No. 1. The end of sash cord at Manhole No. 2 was tied to the punching bag by means of the loop in the cover at the top of the bag. The bag was thoroughly greased before being inserted in the 10-inch line at Manhole No. 2.

The punching bag was drawn in successive 20-foot increments to Manhole No. 1 and the depth of flow in the pipe at Manhole No. 1 was measured at each stage. The decrease in flow was uniform as the plug was drawn through the pipe. There was no abrupt change in the rate of decrease in flow until the plug was drawn to within 150 feet of Manhole No. 1. Over the distance from this point to Manhole No. 1 there was enough decrease in flow to indicate that this portion of the 10-inch sewer had been properly laid and did not allow excessive leakage.

It was concluded from these studies that the ground water infiltration rate for the entire system of sewers in the amount of 26,600 g.p.d. per mile of pipe was excessive; that the infiltration rate to the on-site sewers of 10,740 g.p.d. per mile of pipe was within allowable limits; that most of the excessive infiltration of ground water took place over a distance of approximately 330 feet measured in the direction of flow from

Manhole No. 2; that the sewer from Manhole No. 2 to Manhole No. 1 was reasonably straight and clean and free from bad breaks; and that the excessive infiltration in this sewer was attributable to fairly uniform leakage at the joints.

In view of existing soil conditions, involving the laying of vitrified clay pipe in fine sand under an abnormally high head of water, it was felt that additional precautions should have been taken in specifying the method of pipe-laying.

A new sewer line was recommended for construction between Manhole No. 2 and Manhole No. 0, by-passing Manhole No. 1, a new manhole to be provided midway in this new line. It was further recommended that cast iron pipe be used and that additional construction precautions be taken, including provision for broken stone ballast under and around the pipe, leaving sheeting in place and provision for removal of all ground water from the trench while pipe was being laid.

The new sewer line has been constructed essentially as recommended, abandoning the original lines between Manholes Nos. 2, 1 and 0. The town officials, after inspecting and testing the new line, approved the system.

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TRICKLING FILTERS—PAST, PRESENT, AND FUTURE*

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Over the years much has been written upon trickling filters. A review of the literature shows that the same things have been said over and over. The first papers prepared by the writer some thirty-five years or so ago describe conditions and discuss problems connected with trickling filters which have been described and discussed in many subsequent papers by many authors. To perpetrate another paper upon the general subject of trickling filters seems an unnecessary waste of effort. From time to time, however, it is worth while to survey the past, comment on the present, and predict the future.

The development of the trickling filter had its major inspiration in the work of the Lawrence Experiment Station back in 1889. However, the development of the trickling filter on a practical basis appears due to the work of Corbett at Salford, England. Stoddard of England also carried out experiments on the purification of sewage by application to a filter of coarse material. Colonel Waring, in the early 90's, developed and patented a filter of coarse material utilizing forced aeration. It was not until 1908, however, that the first municipal trickling filter in America was put into service, namely, that at Reading, Pennsylvania. Trickling filters, however, had been in successful use in England for several years prior thereto and it was the demonstration of their effectiveness which led Dr. Rudolph Hering to recommend their installation in this country. Dr. Dunbar in his book "Principles of Sewage Treatment," published in 1907, described a number of trickling filters then in use. Essentially these filters were no different from the standard trickling filter of the present time.

Following the plant at Reading, many other trickling filter plants, both large and small, were installed in American municipalities, the trickling filter plant at Columbus going into operation in the fall of 1908, a few months after the initial operation of the Reading plant. It is probably correct to say that the trickling filter preceded by Imhoff tanks constituted the most popular form of sewage treatment in this country until the middle 1920's. With the development of the activated sludge process the popularity of the trickling filter began to wane. Within the past few years, however, due to the development of the high rate trickling filter as a result of the researches of Jenks, Halvorson, Levine, and others, the trickling filter has been coming back in favor.

Standard Rate vs. High Rate Filters

For many years the accepted rate of treatment with trickling filters ran from two to three million gallons per acre per day. Higher rates,

* A special contribution originally intended for presentation in the technical program of Eighteenth Annual Meeting and Sixth Annual Convention of the Federation, since postponed.

it was felt, would result in undue clogging of the filter material and inadequate purification. In this connection it should be noted that in the early days of sewage treatment one of the criteria used to measure the accomplishment of any sewage purification process was the degree of nitrification obtained. With the development of the biochemical oxygen demand test and its acceptance as a measure of quality, the production of oxidized nitrogen has become of less importance in the eyes of most sanitary engineers. This change of emphasis or change in accepted standard of purification has resulted in the degree of purification effected by high rate filters to be accepted as adequate for many conditions. The high rate filters involve the application of settled sewage at rates from 15 to 25 million gallons per acre per day or rates roughly 8 to 10 times those used in the past for standard filters. In certain types of filters the actual high rates of application result from the recirculation of effluent.

Design Factors

Like the whole subject of trickling filters, the design factors connected therewith have been discussed and written about at length. Again for the purpose of providing some degree of historical perspective and for setting forth what appear to be more or less currently accepted practices, a discussion of design factors appears to be of interest.

Pretreatment

Almost from the very beginning the necessity for adequate pretreatment has been recognized. By adequate pretreatment the load of suspended solids reaching the filters is materially reduced, with accompanying decrease in clogging tendencies. Furthermore, pretreatment prevents or reduces the amount of coarser materials such as match sticks, grease balls, and the like, which choke nozzles and interfere with proper distribution over the surface of the filters. Pretreatment can be accomplished either by sedimentation in plain settling tanks or in Imhoff tanks. At Birmingham, England, the installation some years ago of a modified form of activated sludge prior to the trickling filters was put into effect in order to reduce the load on the filters and to increase their capacity. At Fort Worth, Texas, Mahlie (1) found that he obtained the best results with his filters when the pretreatment consisted of primary sedimentation, aeration and secondary sedimentation. In general, in this country pretreatment consists solely of sedimentation. The accepted detention period approximates 2½ hours for the average daily dry weather flow. There is some evidence that longer periods of sedimentation result in greater capacity of the filters to handle the settled sewage.

In a few large plants, notably Akron and Baltimore, fine mechanical screens have been installed between the primary settling tanks and the filters. The purpose of these screens is to intercept nozzle clogging material. Preaeration, prechlorination, and other methods have been helpful in some places.

Loadings

The loading on a trickling filter may be considered as the volume of settled sewage applied, the pounds of biochemical oxygen demand or pounds of suspended solids applied per unit area or per unit volume of filter. With standard trickling filters, as previously stated, in the past the volume loading may vary from two to three million gallons per acre per day, equivalent to from 250,000 to 375,000 gallons per acre foot based on an 8-foot filter. As regards the biochemical oxygen demand loading, Hall's study (2) of loadings on trickling filters in Ohio indicated that 250 pounds of 5-day B.O.D. could be applied per acre foot daily with the production of a stable effluent. In the case of suspended solids the loadings in pounds ordinarily will amount to something less than the oxygen demand loadings.

For the high rate trickling filters far greater loadings are involved. The high rate of application results in a correspondingly high rate of organic loading, and loadings as high as 3,000 to 4,000 pounds of 5-day B.O.D. per acre-foot have been reported as being handled satisfactorily. In the case of high rate filters, the final effluent, even though showing a relatively high percentage removal, so far as B.O.D. is concerned, will show little in the way of nitrification and will be less stable than the effluent from a standard rate filter. It has always seemed to the writer that the custom of using B.O.D. as the sole criterion for filter loading is not quite right.

In view of the fact that the trickling filter is an oxidizing device it would seem desirable for the influent to contain at least some dissolved oxygen as it comes to the dosing tank. The presence of dissolved oxygen is also desirable from the standpoint of odors. In addition, the quantity and kind of suspended solids applied are a governing factor as well as the oxygen demand. Undoubtedly the more highly clarified an influent the greater the oxygen demand load which can be applied. From a practical operating point of view the fewer large solids, such as grease balls, leaves, lumps of gas-lifted sludge, the higher the loadings which can be successfully dealt with month in and month out.

Depth of Filters

In the early days considerable discussion occurred relative to the economical depth of trickling filters. Here again the measure of accomplishment was a point at issue. It has been demonstrated that the relatively easily oxidizable organic matter was oxidized in the upper three feet or so of the filters and that, as measured by oxygen demand, the purification effected by the lower part of the filter was relatively slight. On the other hand, it has also been shown that the nitrification stage occurs in the lower portion of the filters and that this additional purification results in the production of a more stable effluent than is produced by the shallow depth of filter media. It is obvious that if the loading is based upon the total volume of filter media, the deeper filters are more economical than the shallow filters. For the same volume of

stone the shallow filters will require greater expenditures for distribution and collection than the deeper filters. On the other hand, if the conditions are such that a reasonably well oxidized effluent but one without nitrification is permissible, then the shallow filter dosed at the normal volumetric rates is obviously more economical because of the reduction in the quantity of filter material and media required.

In the case of standard rate filters, engineering practice has been to use filters with depths of six to ten feet. The first Reading filter, only five feet deep, accomplished excellent purification of a well clarified, oxygen bearing influent. Some of the recent high rate filters, particularly where two stages are used, are only three feet deep.

Filter Media

One of the most important considerations in connection with the design, construction, and operation of any type of trickling filter lies in the selection and placing of the filter media. The following quotations from an article by the writer published in 1912 (3) are as true today as when written:

> "It is essential that the greatest care be used in the selection and placing of the filter material; 'just a heap of stones' will not do. Stones should be nearly cubical in form, without cleavage planes and with fairly rough surfaces but not porous. The stone must be hard and not liable to deterioration. Uniformity in size is also necessary to prevent packing, which after a while will cause spots of clogging. If the surface of the material is too smooth, there is less opportunity for the biologic life which plays such an important part in the working of the filters. On the other hand, too rough material tends to retain the accumulated solids and cause pooling and clogging."

The sizes of filter media used in different filters vary quite widely. Some of the early filters used rather small stone while the present tendency with high rate filters is to use large material. Theoretically, fine material by providing greater surface area should give the higher degree of purification. This is offset in part by the tendency of fine material to clog and to accumulate septic sludge. For standard filters, stone size may be from 1½ to 2½ inches, while for high rate filters the stone size may be 3 to 4 inches.

Various materials have been used for filter media, crushed rock, slag, coal, and other substances. Crushed rock is the most common and a hard trap rock or a hard limestone generally works out satisfactorily if care in sizing, grading, cleaning, and placing is exercised.

Dosing Methods

One of the major factors leading to the practical application of trickling filters to the purification of sewage was the development of means for more or less uniformly distributing the sewage over the surface of the filter. Due to the porosity of coarse grained filters, the method of applying sewage by flooding, such as is employed in intermittent sand filters, was not practical. The use of fixed spray nozzles and automatic dosing tanks solved the difficulty connected with this practical

phase of filter design. In this country the general practice in the early days was to use the fixed spray nozzles for distribution. In England, in addition to the fixed spray nozzles such as were used at Birmingham and other places, there were developed traveling distributors, which mechanisms provided uniform application to the surface of the filters. The traveling distributors, however, were never widely adopted in this country until recent years. American engineers were somewhat concerned lest mechanical distibutors would be adversely affected by the more severe winter conditions prevalent in this country as compared with England. Present American practice, however, tends to the greater use of mechanical distributors.

Furthermore, another consideration probably influenced American engineers in the design of dosing methods, namely, the theory developed as a result of intermittent sand filtration practices that a period of resting between doses was desirable to permit the adequate introduction of air into the interstices of the trickling filter bed. This resulted in the use of the fill and draw dosing tank with a resting period for the filter while the dosing tank was filling. A resting period of say six minutes and a dosing period of three minutes would represent a fairly typical dosing cycle. This intermittency of dosing obviously resulted in a very high rate of application to a relatively small portion of the filter area at the beginning of a dosing cycle, which, in turn, would result in variations in the degree of purification effected. This was shown to be so by Johnson (4).

Traveling distributors can be so designed as to give a more uniform and continuous application of sewage to the surface of the bed than is generally the case with dosing tanks and fixed nozzles. In some cases twin dosing tanks have been provided so as to permit more nearly continuous dosing by fixed sprays. This involves arrangements whereby one section of a twin dosing tank will be filling while the other section is discharging. One advantage of continuous application lies in the reduced numbers of the *Psychoda* fly, which will escape from the filter during periods of resting. Continuous dosing by whatever means accomplished tends to prevent the fly from leaving the filter bed even though present.

Ventilation

In the early days of sewage purification investigations and experiments were made and small plants built involving the principle of forced ventilation for coarse grained filters. In recent years some of the investigators of high rate filters have felt that induced ventilation was desirable. Conversely, other investigators have been of the opinion that induced ventilation is not essential provided there is adequate underdrain ventilation. Some filter designers have also felt it helpful to have the filter walls freely ventilated, whereas others have enclosed the walls in concrete. On the whole, the evidence seems to indicate that neither forced ventilation nor porous filter walls are essential.

Underdrains

The underdrainage system is of importance in two particulars: first, for prompt removal of the filtered sewage, and second, for providing ventilation between the top surface of the filter and its under-surface. Many types of underdrainage systems have been devised, each one of which having allegedly superior qualities over other types. It is essential that the underdrainage system be of sufficient capacity to permit ease of inflow and outflow of air and to provide sufficient velocities to prevent accumulations of sludge and grit. In any underdrain system there will be a tendency for organic slimes to grow on exposed surfaces and to accumulate sludge. From time to time these slimes will be sloughed off and the underdrainage system must be capable of handling fairly large pieces of such slimy deposits.

Some filters have been provided with means for flushing underdrains. In general, experience has indicated that with properly designed systems, flushing is seldom if ever required.

Post-Treatment

Due to the sloughing off, either periodic or continuous, of slimes, sludge, and worms, secondary sedimentation is almost always adopted for post-treatment of trickling filter effluents. In a few cases where an extremely high degree of purification has been required, the settled effluent has been applied to intermittent sand filters. At Plainfield, New Jersey, a magnetite filter was installed a few years ago in connection with a new final settling tank but proved unsuccessful and has been abandoned. Where high bacterial removals are necessary, the usual practice is to chlorinate the effluent.

Final settling tanks may or may not be equipped with mechanical means for sludge removal. The tendency is to use mechanical means. The detention periods will run from 1½ to 2½ hours, based on average dry weather flows and on combined flows in case of recirculation of final effluents.

Recirculation

Although, as Imhoff (5) has pointed out, recirculation of effluent was first practiced many years ago, it had received little attention in this country prior to the work of Jenks, Halvorson, and Levine previously referred to. At present recirculation has been used with standard rate as well as with high rate filters.

There are several combinations possible for recirculation. Unsettled filter effluent can be returned either ahead of the primary settling tank or directly ahead of the filter. The same points of return can be used if final settling tank liquor or if final effluent is returned. The evidence as to which of these combinations is the most advantageous is inconclusive. There is much evidence to the effect that recirculation is of considerable value.

Operating Factors

The operation of trickling filters is affected by factors other than design. Some of these factors are beyond the control of either the designer or the operator. Others are controllable.

Temperature

As is true with all processes utilizing biological forces, temperature plays an important part in the functioning of trickling filters. In general, other things being equal, a trickling filter produces the best effluent during the warmer months of the year. If high temperatures result in septic sewage or in the inclusion of gas-lifted solids in the effluent from the primary tank, then the filter may produce a less satisfactory effluent than in the cooler months.

Flora and Fauna

The trickling filter is the habitat of a multitude of living organisms of many kinds. These organisms, both as to numbers and type, are affected greatly by temperatures, food conditions, air supply, and location in the filter. Roughly, the upper three feet of a six-foot filter may be considered as the zone in which oxidation of the readily oxidizable carbonaceous matters occurs and in this zone the protozoa are the significant organisms. The lower three feet constitute the zone in which nitrogenous matters are converted to nitrites and nitrates by nitrifying bacteria.

Microscopic organisms are by no means the only type of biologic life in the filter. Worms of various kinds and the larvae and pupae of insects are likely to be present. The dead and living bodies of these organisms may at times constitute a substantial proportion of the sludge collected in the final settling tanks.

Psychoda

The small moth fly, *Psychoda Alternata*, is the most notorious of the large organisms developing in trickling filters. Its control has been the subject of much investigation and various methods have been tried. With high rate filters and with standard rate filters under practically continuous dosing the numbers of flies leaving the filters are relatively small. Where rest periods occur in the dosing cycle, these flies leave the filters in swarms. The most uniformly successful method for combating this nuisance lies in the periodic flooding of the filters, the frequency of flooding depending upon prevailing temperatures. Some success with chlorination of the filter influent has been reported.

Pooling

A factor which adversely affects the efficiency of purification is that of clogging of the filter media and the pooling of applied sewage. This results in sealing of the filter beds, the stopping of ventilation, and the

production of septic conditions in the sewage and deposits in and on the filter. Pooling results from improper filter media, accumulation of sludge and occasionally from unduly prolific biological growths or inorganic deposits.

Pooling is difficult to correct when it is due to improper filter media. Prevention of pooling by proper selection and placing of the media is, of course, desirable as is the proper operation of the preliminary treatment features so as to preclude clogging materials being discharged upon the filter. Recirculation of a well nitrified effluent has proved advantageous. At times badly clogged and pooling filters have been self-cleaned by the action of the organisms developing in them, particularly the worms. Chlorination has been employed with varying success, in some cases very useful, in others not so useful. Resting has sometimes but not always been helpful.

With high rate filters it is claimed that the continuous unloading characteristic of this type precludes clogging. In this connection it is also claimed that rates of more than 10 m.g.a.d. must be maintained and that rates lower than this rate and higher than about 3 m.g.a.d. will result in clogging. The evidence on this matter is contradictory, but on the whole promising.

Care of Distribution System

Mechanical traveling distributors must be maintained. Automatic siphons require practically no attention. Nozzles must be kept clean if satisfactory distribution is to be attained. Flushing at intervals of the distributing pipes is generally desirable.

Care of Underdrainage System

A properly designed underdrainage system should require practically no care. Under some conditions it may be necessary to flush the system.

Odors

Odors from well operating filters receiving a fresh or well aerated sewage will be slight and relatively inoffensive. In the case of septic sewage, however, the reverse is likely to be true. Chlorination is one remedy, recirculation is another, and preaeration is a third.

Miscellaneous

In general, trickling filters are relatively "shockproof" as regards changes in character and amount of applied sewage. In Germany they have been used as pretreatment for activated sludge. This is contrary to the Birmingham method of bio-aeration ahead of trickling filters.

The winter operation of trickling filters is not a particularly serious problem if proper dosing rates are used. Ice formation is usually of little significance.

The sludge collected in the secondary settling tanks varies in amount and character depending upon the extent of unloading and the biologic life in the filters. The efficiency of final settling tanks is often hard to determine by analyses of influent and effluent, due to the difficulty of obtaining representative samples of influent. Some of the early trickling filter plants were built without final settling tanks. This was before it was realized that secondary sludge could be large in volume and often most offensive. Its disposal is often not one of the least of the operator's problems. Digestion with the primary sludge, either in separate tanks or in Imhoff tanks is generally used. As a rule undigested secondary sludge does not dewater readily when applied to sand beds.

Purification Effected

Records of trickling filter plant operation show wide variations in purification effected. Such variations are due to a diversity of causes such as design factors, loadings, methods of operation, character of sewage, climatic and other local conditions. From the practical standpoint the overall efficiency of a treatment plant and the character of the effluent are the significant facts as regards stream pollution. From the technical angle, however, the work accomplished by the filter alone or by the filter plus its final settling tank is of considerable interest.

Biochemical Oxygen

In the case of standard rate filter plants operating with settled sewage of normal character, an overall yearly average oxygen demand reduction of about 85 per cent may be expected. Of this reduction about one-third will be accomplished by the primary tank and the remaining two-thirds by the filters and final tank. Higher removals have been reported from plants using recirculation.

High rate filter plants will bring about nearly as great oxygen demand removals, say 75 to 80 per cent. With two-stage filters results comparable with standard filters appear possible.

Suspended Solids

Trickling filters alone do not materially reduce the quantity of suspended solids applied. They agglomerate finely divided and colloidal solids and alternately store and discharge solids. At times analyses of influent and effluent will indicate the removal of suspended solids but at other times the effluent will contain such solids far in excess of those present in the applied sewage. It is probably true that if a really accurate determination of applied and discharged suspended solids were possible, the incoming and outgoing solids would balance. The applied and discharged solids differ radically in character, however, due to physical and chemical changes brought about by the filter and by the production of solids in the form of dead and living organisms not present in the applied sewage.

Nitrification

The old criterion of nitrate formation continues to be a useful measure of filter effectiveness where a high degree of purification is required. It should be remembered that one part per million of nitrogen as nitrate represents nearly three and one-half parts of oxygen in combined form.

Standard rate filters will produce an effluent with 5 to 10 p.p.m. of nitrogen as nitrates. High rate filters will ordinarily accomplish little nitrification even though their oxygen demand reductions will approach those of standard filters.

This difference in nitrification effected explains in part at least why a high rate filter effluent containing approximately the same amount of oxygen demand as that from a standard filter will be stable for less than a day, whereas the standard filter effluent will be stable indefinitely. For example, assume a high rate effluent with 30 p.p.m. of 5-day B.O.D., 5 p.p.m. of dissolved oxygen, and no oxidized nitrogen. The 30 p.p.m. of 5-day B.O.D. is equivalent to about 9 p.p.m. of 1-day B.O.D., to satisfy which there is available only 5 p.p.m. of dissolved oxygen. On the other hand, assume a standard filter effluent with 25 p.p.m. oxygen demand, the 5 p.p.m. dissolved oxygen and 5 p.p.m. of nitrate nitrogen. Neglecting the nitrite nitrogen, there will be 22 p.p.m. of oxygen available, practically enough to satisfy the 5-day demand. On the comparison of the oxygen demand and dissolved oxygen figures there would appear to be little choice as between the two effluents. It is obvious, however, that the effect of the effluents in a small volume of diluting water would be quite different.

Future Prospects of Trickling Filters

The relatively recent revival of interest in trickling filters will probably continue. The use of high rate filters will increase where the ultimate in purification is not required but where a better effluent than that produced by sedimentation alone is necessary. Where a well purified effluent is called for, standard rate filters will be provided more and more with means for recirculation of effluent. Experiences at Plainfield, N. J., and San Bernardino, Calif., point the ways by which improved operating results may be obtained with standard filters.

There are a number of questions relative to trickling filters for which conclusive answers remain to be obtained. For example, in the case of recirculation, the best points to take and to discharge recirculated liquor have not been definitely demonstrated.

One of the faults with much of the data available is the presence of so many simultaneous variables which make definite deductions impossible. Again using the matter of recirculation as an example, whether for high rate or standard filters, there are at least four methods which should be investigated. To produce conclusive results, four outdoor pilot plants of substantial size should be operated with every condition the same except the source and point of discharge of the recirculated effluent. These plants should be operated for eighteen months to allow

for the establishment of reasonably stable conditions and to cover one whole cycle of inescapable seasonal changes.

It is interesting to note, in conclusion, that after fifty years of trickling filter experience, there is still opportunity for research with them.

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Industrial Wastes

TREATMENT AND DISPOSAL OF SPENT PICKLING LIQUORS *

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One of the important operations in the production of certain steel products is the removal of the oxide scale from their surfaces. During the course of their manufacture, such major products as tin plate, sheets, strip, wire, and galvanized pipe are suitably treated for that purpose. For many reasons the operation is an essential one and the practice is widespread, both at steel mills and at various fabricating plants. The removal of scale is usually effected by immersing the product in an acid bath for a relatively brief period. This process is called "pickling."

A number of acids (sulfuric, hydrochloric, nitric, phosphoric, hydrofluoric) are used in pickling steel; but in comparison with sulfuric acid the quantity of other acids so employed is small, and, in this paper, pickle liquor will refer to a sulfuric acid solution unless otherwise noted.

The acid concentration of a pickling bath is gradually reduced as the acid reacts with the metal oxides and with some base metal. Finally there results an aqueous solution of free acid and metal salt which is no longer an effective pickling agent; this spent liquor has constituted a disposal problem in the steel industry for more than sixty years.

Not the least obstacle to solving the pickle liquor disposal problem has been the rapid growth of the industry. In 1891 less than 1,000 tons of tin, terne, and black plate were produced in the United States; in 1941, the latest normal year for which data are available, 4,328,000 net tons were manufactured (1). In the same year 5,746,000 net tons of full finished sheets, strip, and flat galvanized products were made. The future annual rate of production will doubtless be considerably in excess of these figures.

Steel is pickled in both batch and continuous equipment. In the former, the products are suspended in an acid bath, with or without agitation, until pickling is complete; the time of immersion varies from about ten minutes to an hour or more. The spent liquor usually contains from 0.5 to 2 per cent free acid and 15 to 22 per cent ferrous sulfate. In continuous pickling, steel strip from a coil passes through a scale-breaker, an automatic welder or stitcher where a fresh coil can be joined to the end of the strip ahead, a series of tanks containing pickling

* A special contribution originally intended for presentation in the technical program of the Eighteenth Annual Meeting and Sixth Annual Convention of the Federation, since postponed.

liquor, and a rinsing device and dryer; finally it is re-coiled. The strip passes through the pickler at such a speed that the total immersion time per unit area is approximately a minute. The waste liquor from a continous pickler generally averages 4 to 7 per cent free acid and 14 to 16 per cent ferrous sulfate. Estimates of the annual production of spent liquor vary somewhat, but in a normal year probably about 600,000,000 gallons would be made. The unobjectionable disposal of this large volume of waste liquor is a problem of considerable magnitude.

Disposal Without Treatment

A number of methods are in use or have been proposed for disposing of spent liquors without treatment. Examples of such procedures are discharge into deep wells, fissures in cavernous limestone, abandoned mines, exhausted oil and gas sands, artificial lagoons, gravel sumps near large bodies of water, and sewers terminating in rivers, lakes or tidewater. There are objections to each of these expedients.

Wells and limestone fissures eventually refuse to accept any more liquor through sealing of permeable strata by deposition of reaction products. In some cases pollution of ground water might occur.

Artificial lagoons, which depend on a combination of bottom seepage and solar evaporation, are used at a number of plants but they usually require a larger ground area than is available at most mills.

Gravel sumps adjacent to large bodies of water have been utilized successfully, but construction of new pits is necessary as the old ones are sealed by the action of the liquor.

Direct discharge into large bodies of water or rivers is sometimes the only means of disposal which can be employed without incurring excessive cost. Although the pollutional effect of the liquor is small compared with that of domestic sewage, mine drainage, or organic industrial wastes, oxidation of the ferrous iron colors the receiving water brown in localized areas, particularly in periods of low water, and its appearance becomes esthetically objectionable.

Neutralization

The treatment of waste pickle liquor with an alkaline agent provides a simple, though expensive, process either for neutralization of the free acid alone or for complete precipitation of the iron. A number of methods have been proposed, or are in use, which employ this type of treatment.

Where companies have permission to discharge the spent liquor into municipal sewerage, provided the free acid has first been neutralized, soda ash is usually used to avoid the increase in settleable solids which would occur if lime were employed. In some cases, however, lime is used to neutralize the free acid and the resulting suspension is pumped to lagoons where the ferrous iron gradually oxidizes and precipitates as hydrated ferric oxide.

The most common treatment of this type is the addition of sufficient lime slurry for complete precipitation of the iron; the mixture is then discharged to a lagoon where the substrate is allowed to disappear by evaporation and bottom seepage. In some cases the iron-free supernatant flows over a weir into a stream or sewer. This procedure is expensive not only because of the lime required (roughly one pound per gallon of average liquor) but also owing to the facts that a substantial land area is needed and that accumulated sludge must be removed from the lagoon from time to time. It has been reported from several sources that the cost of this type of treatment is practically the same as the cost of pickling.

Treament of the liquor by permitting it to percolate through beds of crushed limestone has generally been unsuccessful because of the deposition of an impervious layer of calcium sulfate on the stone, thereby reducing the efficiency of the process almost to zero.

Among the other processes of this kind which have been proposed are the Dorr (2), which comprises addition of pulverized limestone with vigorous air agitation and recirculation of a portion of the suspension; the Travers (3), wherein marl is used as the alkaline agent, which is reported to produce a sludge that can be used in the treatment of organic wastes and sewage; and reaction with ground basic slag, which has proved unsatisfactory because of the evolution of hydrogen sulfide and the low available basicity of most slags. None of the processes mentioned in this paragraph is in commercial operation.

The cost of lime treatment suggested the development of a split limestone-lime process (4), wherein pulverized limestone would be used to neutralize the free acid and precipitate part of the iron, and lime slurry would then be added to complete the treatment. Such a process was tried, first on a laboratory scale, then in an industrial demonstration lasting six months. In areas where pulverized limestone is cheap compared with its chemical equivalent as lime the process is substantially more economical than treatment with lime alone. Equipment is being installed at the plant of the Sharon Steel Corporation, where the commercial trial was made, to provide for storage and feeding of bulk pulverized limestone, whereby greater raw material economies will ensue.

By-product Recovery

The recovery of by-products from spent liquor has engaged the attention of many research workers. In consequence a large number of processes have been patented; few of them, however, have ever been used commercially.

The processes thus proposed may be classified into general types, as follows: Those in which the primary product is (a) an iron salt, (b) sulfuric acid, (c) electrolytic iron, (d) a pigment composition, (e) building material, (f) ammonium sulfate. Most of these classes have less important by-products which are, however, essential to process economy. In addition there are a number of miscellaneous procedures which have been devised to manufacture other compounds.

Iron Salts

Copperas, $FeSO_4 \cdot 7H_2O$, is the by-product which can be made most easily from waste pickle liquor (5). This compound is usually manufactured by neutralizing the free acid in the liquor with scrap iron, settling to remove suspended solids, evaporating or refrigerating to crystallize the copperas, centrifuging to separate the crystals from the mother liquor, and drying the product. By carefully controlled drying of copperas, side rotile, $FeSO_4 \cdot 5H_2O$, can be produced; this compound contains 37.2 per cent of water against 45.3 per cent for copperas, and its solubility is unaffected by the drying operation.

It has seemed desirable to many investigators to recover the free acid from spent liquor, as well as the copperas, and a variety of processes have been described to accomplish this result. Evaporation, refrigeration, employment of sulfuric acid to reduce the solubility of ferrous sulfate, addition of ferrous sulfate monohydrate to take up water, and use of differential solvents are expedients which have been proposed for application singly or in various combinations. The end result of all these processes is the same: The separation of copperas crystals from a dilute sulfuric acid solution suitable for the return to the picklers. The use of recovered acid for pickling has not been generally accepted by the industry because of the accumulation of deleterious impurities in the liquor. A number of the most important processes in this group are listed in the appended bibliography (6).

The high water content of crystal copperas precludes shipping this compound to relatively distant points. With the so-called monohydrate of ferrous sulfate, which contains approximately 1½ molecules of water of crystallization, equivalent to about 15 per cent of water, this difficulty is not encountered and therefore much research has been devoted to its production from waste pickle liquor. The processes evolved include carefully regulated drying of copperas; direct dehydration (7) of the spent liquor in which the free acid has been neutralized with iron oxide; spray drying (8) of the neutralized liquor; evaporation in vacuum evaporators until the concentration of sulfuric acid reaches about 78 per cent (9), at which concentration ferrous sulfate is insoluble in sulfuric acid and is precipitated as the monohydrate; heating the liquor with live steam to about 350° F. in an autoclave (10) and filtering the precipitated monohydrate without reducing temperature or pressure. The monohydrate is the preferred form of ferrous sulfate for manufacturing sulfuric acid, because it can be roasted directly to liberate oxides of sulfur.

Several procedures have been developed for producing ferric sulfate from waste pickle liquor (11). The processes differ somewhat in particulars, but the principle in each is the oxidation of ferrous sulfate with a stream of air containing sulfur dioxide. Good results have been reported from the use of the ferric sulfate solution so obtained, either alone or chlorinated, in the purification of water and the treatment of sewage, at a marked saving in operating cost.

A process has been patented for manufacturing ferric phosphate

(12) from spent liquor by treating it with pulverized phosphate rock. It is claimed that the compound so produced is valuable as a coagulant in water purification and sewage treatment; in the case of the latter, an increased fertilizer value for the sewage sludge is cited as an advantage.

Sulfuric Acid

Conversion of iron sulfate into sulfuric acid, with sintering of the residual iron oxide for charging to blast furnaces, has appeared to be a logical solution to the waste pickle liquor problem, and there has been considerable investigation in this direction. Copperas cannot be roasted directly to produce oxides of sulfur, however, because it melts in its water of crystallization and thereby causes engineering difficulties; it must first be converted to the monohydrate. Methods proposed for recovering ferrous sulfate monohydrate from spent liquor have been dealt with in the preceding section.

Although the manufacture of sulfuric acid from iron sulfate is entirely practicable, the cost of the equipment and its maintenance is high. Also, to be economically sound, a plant must produce a minimum of about 100 tons of concentrated acid per day. As no single steel mill produces enough waste pickle liquor to support a plant of this size, it would be necessary to work a cooperative acid plant to convert the monohydrate recovered in several mills comprising a steel district. Such a plant has been discussed from time to time, but transportation and other physical difficulties have posed serious obstacles. An alternative scheme embraces utilization of existing acid plants whereby the owners of such plants would process, for a conversion charge, the monohydrate produced by the steel mills. On the whole, despite the logic of such an operation, the manufacture of sulfuric acid is not always attractive from the viewpoint of overall economy.

Electrolytic Iron

Recovery of metallic iron from waste pickle liquor by electrolysis has excited the interest of a number of research workers. Several processes have been patented (13) and others are in process of development. The tendency of ferrous ions to oxidize to ferric ions and precipitate basic salts is an obstacle to the practical electrodeposition of iron. Maintaining an acid bath to avoid this tendency involves the necessity of frequent regulation of the acidity because, iron being above hydrogen in the electromotive series, unless the Fe^{++}/H^{+} ratio can be kept high, considerable hydrogen plates out with the iron, reducing cell efficiency.

It is said that difficulties involved in the economic production of electrolytic iron have been overcome, but details are not available.

Iron Oxide Pigments

Natural iron oxides have been used as coloring materials since ancient times and similar pigments have been manufactured for many

years by thermal decomposition of copperas. A number of processes have been set forth for making pigments from waste pickle liquor and several of them are in commercial operation. In some cases the actual means by which iron salts are converted into oxides are closely guarded and little has been divulged about them. This situation is caused by the fact that production of pigments of high quality and constant uniformity is at present an art rather than a technology.

Several processes (14) have been described briefly. A British procedure treats pickle liquor with scrap iron to neutralize the free acid, spray-dries the liquor, and calcines the resulting monohydrate in a carefully regulated continuous furnace. The evolved oxides of sulfur are neutralized in a lime tower. Two other processes convert the sulfate liquor to a chloride solution by treatment with calcium chloride. The resulting material can be calcined to produce pigments of several different colors. In a German process, waste pickle liquor is treated with sodium sulfate, and a double salt of iron and sodium sulfate is crystallized and roasted at about 700° C. The product is leached to recover the sodium sulfate and the iron oxide is calcined. In another process, pickle liquor is treated with soda ash or ammonia, the precipitate oxidized with air, filtered off and autoclaved at about 100 p.s.i. The pigment produced contains 97.3 per cent ferric oxide.

Although no serious problems are involved in manufacturing pigments from waste pickle liquor the market for such materials is so limited that their production would be far from an adequate solution of the spent liquor disposal problem. A relatively small fraction of spent liquor available annually would supply the pigment requirements of the country.

Constructional Products

A process (15) with interesting possibilities has been developed to produce a building material, called Ferron, from waste pickle liquor. The spent liquor is treated with milk of lime under carefully controlled conditions of temperature, concentration and pH, the suspension is filtered, and the filter cakes are blended in pug mill. The plastic material is extruded in the form of blocks or bars and dried at 175° F. While drying, the ferrous hydrate oxidizes to hydrated ferric oxide and the product loses its plasticity. It can be sawed or machined into various shapes without difficulty. Blended with a fibrous filler the plastic material can be pressed into sheets before drying and in this form it provides a fireproof wallboard with a low coefficient of heat transfer; it is also reported to have good acoustic properties. By incorporation of an asphalt emulsion with the plastic material it is claimed that a shingle of promise can be made.

Ammonium Sulfate

Steel mills operating by-product coke ovens as well as pickling departments would appear offhand to possess a ready-made process for pickle liquor treatment whereby iron oxide and ammonium sulfate

could be manufactured. There are several reasons why this is not the case. Pickle liquor and ammonia liquor contain a variety of impurities (inhibitors, wetting agents, cyanides, sulfides, cyanates, etc.) which result in the production of an impure ammonium sulfate unacceptable to fertilizer manufacturers, who consume by far the highest proportion of this chemical. Removal of the impurities is usually an expensive procedure. Ferrous hydroxide is a difficult substance to filter and costly expedients must be adopted to convert the precipitated iron compounds into a readily filterable form. Evaporation of the large quantities of water to crystallize ammonium sulfate is expensive because, contrary to general belief, steel mills have little available waste heat. Finally, the lack of stoichiometric proportions would normally require extensive storage because, when the general production rate rises the coke oven production increases first, resulting in a surplus of ammonia liquor, and, when the rate falls, the opposite sequence occurs, whereby an excess of pickle liquor is produced.

Notwithstanding these difficulties, a number of processes (16) have been described in the literature. Early patents provided for the purification of ammonia liquor by adding sufficient pickle liquor to precipitate the impurities; the purified liquor was then treated with pickle liquor equivalent to the ammonia, and air was blown into the suspension to oxidize the precipitated iron, which was filtered off and sintered for blast-furnace burden. Ammonium sulfate was crystallized from the filtrate. In another patented process the pickle liquor, at 150° C., was allowed to flow down a vertical packed tower in which it met a countercurrent stream of air and ammonia gas pumped into the bottom of the tower at about 100 p.s.i. It was claimed that hydrated iron oxide was precipitated in a readily filterable form and that ammonium sulfate was recoverable from the filtrate. One process proposed washing coke-oven gas with hot pickle liquor to precipitate the iron as a sulfide, which filters easily, and recovering ammonium sulfate from the filtrate. In another group of patents pickle liquor was treated with an excess of ammonia gas whereby 60–80 per cent of the iron was precipitated and filtered off. The filtrate was treated with ammonia gas containing hydrogen sulfide and or carbon dioxide to precipitate the remainder of the iron. A German process treated pickle liquor with a slight excess of lime; the suspension was filtered and flue gas passed through sludge mixed with twice its weight of water to convert the lime to calcium carbonate. Raw ammonia gas and carbon dioxide were then passed through the suspension to yield a mixture of calcium carbonate, ammonium sulfate, hydrated ferric oxide, and basic iron sulfate. The suspension was filtered and ammonium sulfate crystallized from the filtrate; the filter cake was dried and sintered to yield a mixture of lime and iron oxide for blast furnace charging. Another German process involved exposing ferrous sulfate trihydrate to ammonia and air which yielded a coarse, semi-crystalline mixture of ferric hydrate and ammonium sulfate. The product was leached with hot mother liquor from previous ammonium sulfate crystallizations and the iron oxide remaining could

be used for gas purification, roasted to a pigment, or sintered for blast-furnace charge.

Miscellaneous Processes

Quite a number of unclassified processes, most of which are still in the developmental stage, have been proposed for utilizing spent pickling liquors. Several of the more suggestive of them will now be described.

Ferrous sulfate in pickle liquor is oxidized, then hydrolyzed in an autoclave by direct injection of steam at 100–200 p.s.i. Addition of sodium sulfate and ferric oxide then results, under proper conditions, in the formation of sodium natrojarosite, $Na_2Fe_6(OH)_{12}\cdot(SO_4)_4$, which is separated, dried, and calcined to form a soluble ferric salt for use as a coagulant. The method is reported to remove 95 per cent of the iron from waste pickle liquor.

In another process the free acid is neutralized with scrap iron and the solution treated with zinc or a zinc compound. A suspension of iron as a fine, black powder (soot iron) forms and is filtered on a bed of special material from which useful aluminum salts are said to be produced.

Considerable research has been in progress on the treatment of pickle liquor with soda ash to recover sodium sulfate and iron carbonate. Although sodium sulfate has a market of considerable size in the glass, textile, pulp and paper industries, the cost of soda ash, the evaporation of large volumes of water, and the undesirability of iron carbonate as a blast-furnace charge render such a process infeasible, or comparatively unattractive.

A process based on the metal sulfate-metal sulfide cycle consists of treating the spent liquor with barium sulfide, conducting the evolved hydrogen sulfide to a plant for conversion to sulfuric acid, dewatering the sludge, mixing it with coke or coal, and roasting it in a reducing furnace. The resulting black ash is leached, the solution of barium sulfide returned to the process, and the insoluble residue hauled to a dump.

Mellon Institute Research in this Field

The first concerted attack on the problem of waste pickle liquor disposal was begun when the American Iron and Steel Institute established a fellowship, under the direction of Prof. W. W. Hodge and sponsored by its Stream Pollution Committee, at Mellon Institute in 1938.

The first project of the fellowship was a thorough review of past research on the problem and the direct collection of data from steel mills. Most of the processes which had been proposed were economically or technically impracticable; the more promising of these processes have been briefly described in this paper. This investigation of past developments involved a painstaking search of the literature, a large amount of correspondence and many conferences with inventors of processes, and economic evaluations. The results were published by Hodge (16A)

under the title "Waste Problems of the Iron and Steel Industry." The present paper is partly a selective condensation of the prior article.

This study showed that not only was there no single process for the manufacture of useful by-products which would solve the problem for the entire industry, but that no economically sound process existed which would adequately serve the need of the individual mill, whether large or small. Several plants were producing copperas, frequently at a loss, and they were able to supply the market for this compound by utilizing less than 5 per cent of the liquor produced. Simple lime neutralization plants were in operation at many mills, but this disposal method is not only costly but it yields, instead of a useful by-product, another waste which must be accumulated in dumps.

While continuing its investigation of many processes with potential value, the fellowship began its own research program which expanded gradually until practically all its time is now devoted to original studies. This program brought to light a number of interesting possibilities of which several are still in the developmental stage. It has been feasible to study the processes which have originated at Mellon Institute only on a laboratory scale because the advent of the war precluded the pilot-plant investigations which are essential to satisfactory economic evaluation. The fellowship has hesitated to publish its research findings until pilot-plant operation has been concluded on each process so that complete descriptions could be presented. Pilot-plant investigations are planned for the time when equipment again becomes generally available.

Certain fellowship processes will be mentioned specifically in passing. One research project showed that iron sulfate could be substituted for gypsum to control the setting time of Portland cement (17). If iron sulfates could generally be substituted for the gypsum added to cement, the bulk of the copperas produced in spent pickle liquor could be utilized in this field alone. Iron sulfates used for this purpose produce a cement with a cream color, rather than the normal gray-white; and while there should be no objection to the color per se (the darker shade would be definitely advantageous for concrete highways), A. S. T. M. specifications and contractors' buying habits would have to be modified before this market could be cultivated with success.

A new process for recovering copperas from pickle liquor was developed (18) wherein the property of certain organic solvents of reducing the solubility of ferrous sulfate was employed. The effects of a large number of solvents were studied and acetone was found to be the most practicable agent. Combination of equal volumes of pickle liquor and acetone resulted in the precipitation of approximately 95 per cent of the ferrous sulfate as copperas. Acetone was recovered from the mother liquor by distillation and the bottoms from the still contained practically all the free acid present in the original liquor. When sufficient sulfuric acid was added to the recovered liquor to bring it up to pickling strength, a solution was obtained which contained two per cent or less ferrous sulfate.

Comparisons were made between pickling solutions prepared with fresh sulfuric acid and with acid recovered by this process, and it was found, after six pickling and recovery cycles, that there was no tendency for impurities to accumulate in the recovered acid and that it was equivalent to fresh acid as a pickling agent.

The split limestone-lime process (4) was developed to reduce the cost of neutralization treatment for companies situated where pulverized limestone can be obtained at low cost. Under optimum conditions this process results in significant economies.

Other processes, of which the details cannot be revealed at present, include the manufacture of sodium sulfate and ferric chloride, manganese concentrate from low-grade ores, magnesia, plaster of Paris, and magnetic iron oxide. All these procedures utilize waste pickle liquor and yield only a small amount of residual waste, which can be discharged to streams or municipal sewerage without cause for complaint.

Conclusion

A brief review of the many processes offered for waste pickle liquor treatment has been presented. Limitation of space has necessitated a summary description, but a comprehensive select bibliography has been appended for those specialists who desire more information.

The disposal of spent liquor is an onerous problem because the compounds which can easily be recovered or derived therefrom normally have such low values that only the simplest and most economical processes can be employed. Thus far, the possibility of realizing a financial profit from the treatment or disposal of waste pickle liquor is not at all promising. A self-sustaining process would be accorded due attention, and even processes which might be able to sustain only a reasonable proportion of the operating cost are continually under investigation. Unfortunately, however, economic analysis shows that most of the processes which have been operated on a pilot-plant scale and which afford marketable by-products are costly or are not adaptable to operation in the mills.

The recovery of copperas from pickle liquor is an established operation, but it supplies only a partial solution to the spent liquor disposal problem because of the limited market for this compound. Water purification and also sewage and industrial waste treatment provide large potential markets for iron salts and interest in this field has been increasing in recent years. Ferrous sulfate, oxidized with chlorine or used in combination with lime and other chemicals, furnishes a coagulant (19) which performs satisfactorily over a much wider pH range and is more effective in removing color than aluminum sulfate. Iron salts are being used in chemical treatment of sewage and industrial wastes at a number of plants. Combination of copperas with activated silica has been reported from several sources (20) to give excellent results as a sewage coagulant and further developmental work in progress. Use of silica avoids the necessity for chlorinating the copperas.

Further plant-scale tests with iron salts should be conducted to establish the conditions under which iron salts are superior to and more economical than other coagulants.

Return of the country to normality after the war will encourage a considerable expansion of research in the field of waste treatment. The earnest application of scientific investigation to treatment problems will bring many new processes whose value will have to be demonstrated to mill operators by actual factory trials so that their advantages may be successfully utilized.

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FREEZING AS A FACTOR IN THE STABILIZATION OF CORN CANNERY WASTES

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The major purpose of an impounding lagoon is to store the waste until it has undergone sufficient decomposition and reduction in strength so that its release during periods of high stream flow will not seriously deplete the oxygen resources of the receiving waters. Over a period of several years the analysis of routine samples of frozen waste from lagoons has shown consistently lowered biochemical oxygen demand values. Reductions have been noted from a raw strength of 2,000 parts per million to 500 parts per million, and sometimes to as low as 30 parts per million five-day biochemical oxygen demand. Graphs I and V show the five-day biochemical oxygen demand results of recent tests. The frozen wastes have also shown marked reduction in total solids, suspended solids, total volatile matter and total suspended volatile matter. At the same time, in each case the settleable solids in the melted ice showed marked increases over the settleable solids found in unfrozen samples of the waste.

Freezing as a Factor

From these observations the question arose as to just what part, if any, freezing plays in the overall stabilization of lagooned corn canning waste. This question eventually led to the present set of experiments of freezing corn waste under controlled conditions.

It is a well-known principle of chemistry that freezing or crystallization of a solution generally tends to result in a concentration of the solute in the unfrozen (uncrystallized) liquid or in a precipitation of the solute as its limit of solubility is exceeded. It was the recognition of this principle that formed the basis of these experiments. In this set of experiments no studies were made relative to the release of colloidal constituents or dissolved matter before crystallization actually began. While it is considered possible that the lower solubility of some of these substances at low temperatures may result in their release from solution before freezing begins, the cooling of the waste down to a point where freezing can begin, so far as these experiments are concerned, must be considered as an essential preliminary step. Future studies may give consideration to measurements of the effect of cooling alone.

Experimental Procedure

Equipment

The actual freezing of the samples was carried out in a refrigerated, insulated room with forced circulation. The temperature was maintained at -10° F. (variation not over 2 to 3° F.).

In order to simulate field conditions of freezing from the surface of the liquid down, the samples were frozen in galvanized sheet metal cones which were insulated in sawdust-filled boxes. The minimum layer of sawdust at any given point on the cone's surface was four inches. The diameter of the base of the cone was twenty inches, the depth eleven inches, and the volume about twelve liters (Figure 1).

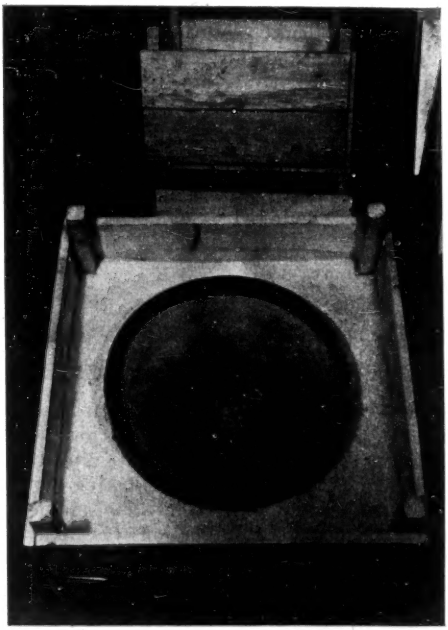


FIG. 1.—View of insulated boxes with sheet metal cone in place.

Methods and Samples

For purposes of convenience most of the sampling was done at Cokato, Minnesota, where varying volumes of waste up to ten gallons were collected once each week. The temperature of the waste was always kept below 40° F. On return to the laboratory, a two-liter portion was analyzed immediately for the following: pH, five-day biochemical oxygen demand, ten-day biochemical oxygen demand, settleable solids, total solids, total volatile matter, total suspended solids and total suspended volatile matter. All determinations were carried out as directed in *Standard Methods of Water and Sewage Analysis*. Most biochemical oxygen demand determinations were made with fortified formula "C" water (Nichols and Lea), although some of the results

on the first samples were based upon bicarbonate dilution water. The dilution water in all cases was seeded with 1 cc. of settled sewage per liter of dilution water.

One or more portions of the remaining samples were then completely frozen. Although less than 24 hours is required to freeze the cones solid, several of the frozen samples were "aged" for varying lengths of time (a few days to several weeks). It was hoped that this procedure would indicate whether prolonged "aging" added any further contribution to the stabilization of the waste. Other variations in freezing technique included partial freezing.

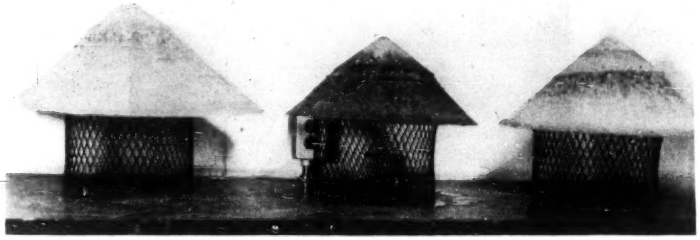


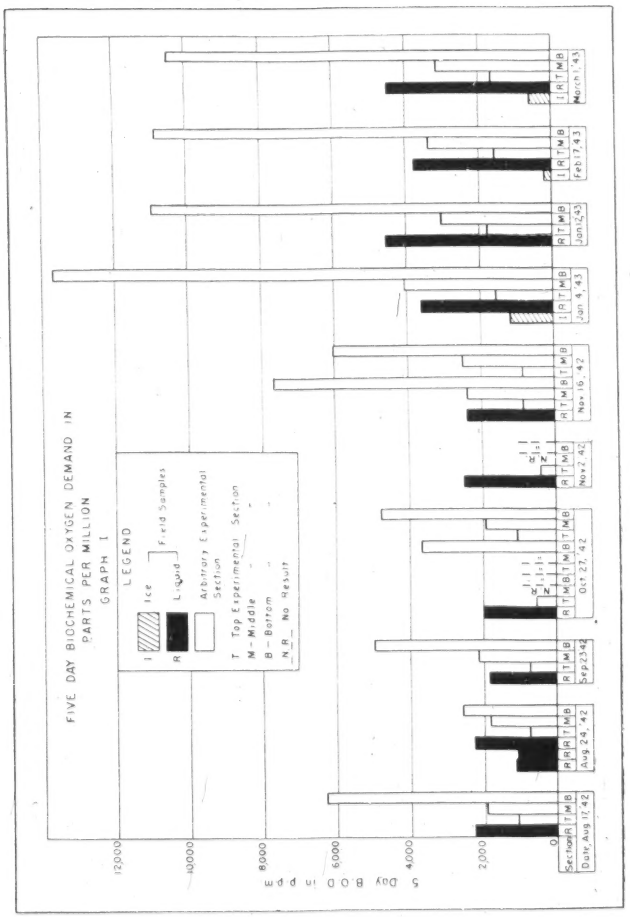
FIG. 2.—Typical cones of frozen corn waste.

In most of the tests, the cone of ice (Figure 2) was mechanically separated into three arbitrary sections from top to bottom. From each of the three sections approximately 1½ liters were melted as rapidly as possible in a warm-water bath, taking care not to let the temperature rise much above 32° F. These sub-samples were analyzed in the same way that the two-liter portion was analyzed. The tests were carried out continuously from August, 1942, to April, 1943.

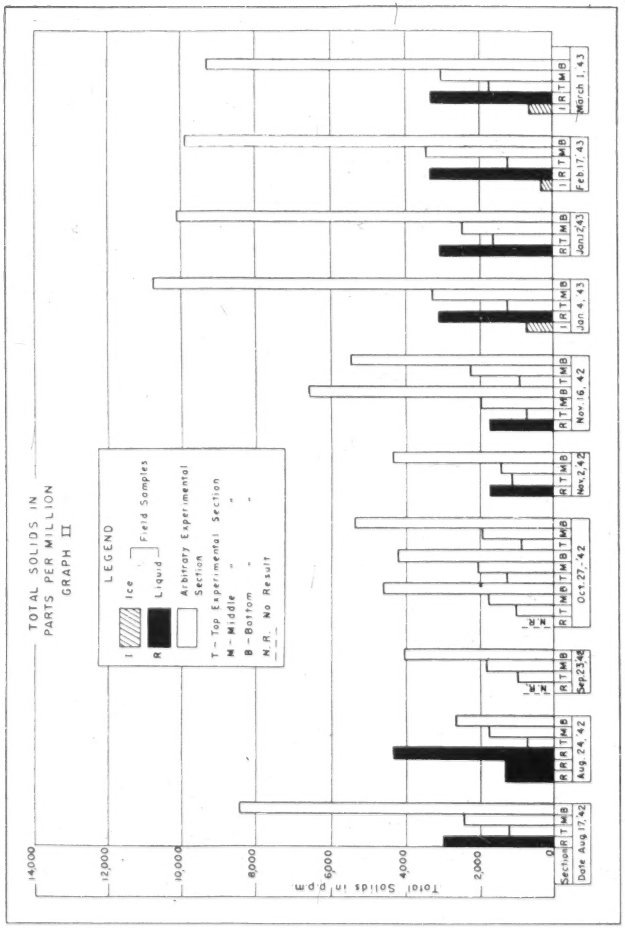
EXPERIMENTAL RESULTS

Biochemical Oxygen Demand

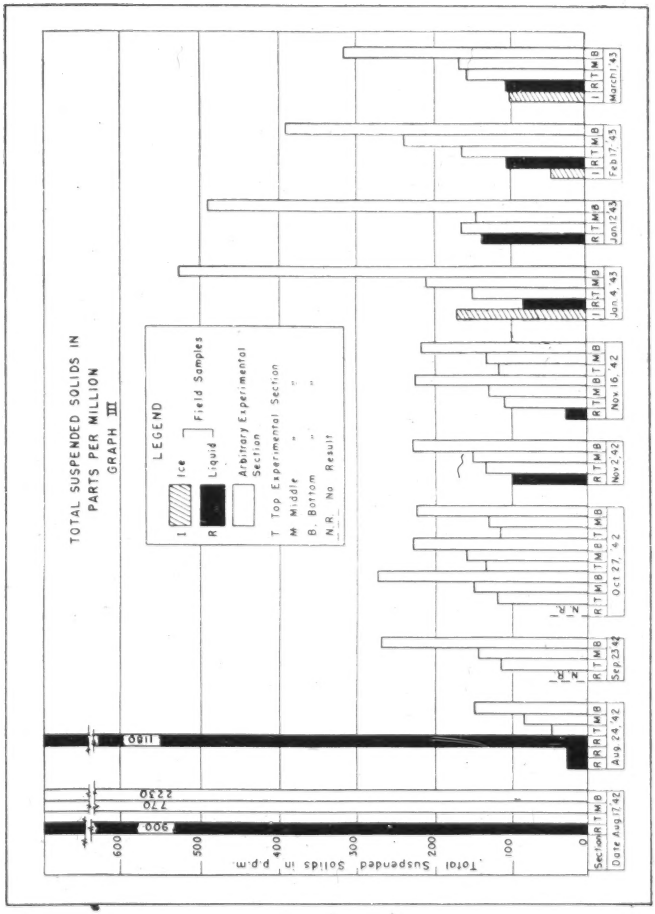
The top section invariably had a much smaller five-day biochemical oxygen demand than did the raw samples (Graph I). Total solids showed a marked decrease in each case (Graph II). On the other hand, Graphs III and IV show that an increase in total suspended solids and settleable solids was consistently noted. The middle section consistently showed the same trends as the top section but to a more marked degree. The bottom section showed the greatest variation from the raw sample. In many cases, the five-day biochemical oxygen demand of the bottom section was two to three times that of the raw, five to ten times that of the top layer, and three to four times that of the middle layer. At the outset of these experiments it was assumed that there would be a concentration of strength in the lower layers of ice or liquids under the ice. This set of experiments measures the concentration and confirms the correctness of the assumption.


FIVE DAY BIOCHEMICAL OXYGEN DEMAND IN PARTS PER MILLION
GRAPH I
LEGEND
I Ice
L Liquid
Field Samples
R Arbitrary Experimental Section
T Top Experimental Section
M - Middle
B - Bottom
N.R. No Result
5 Day B.O.D. in p.p.m.
12000
10000
8000
6000
4000
2000
0
Section R T M B
Date Aug. 12, 42
Aug. 24, 42
Sept. 2, 42
Oct. 27, 42
Nov. 2, 42
Nov. 16, 42
Jan. 4, 43
Jan. 12, 43
Feb. 17, 43
March 1, 43

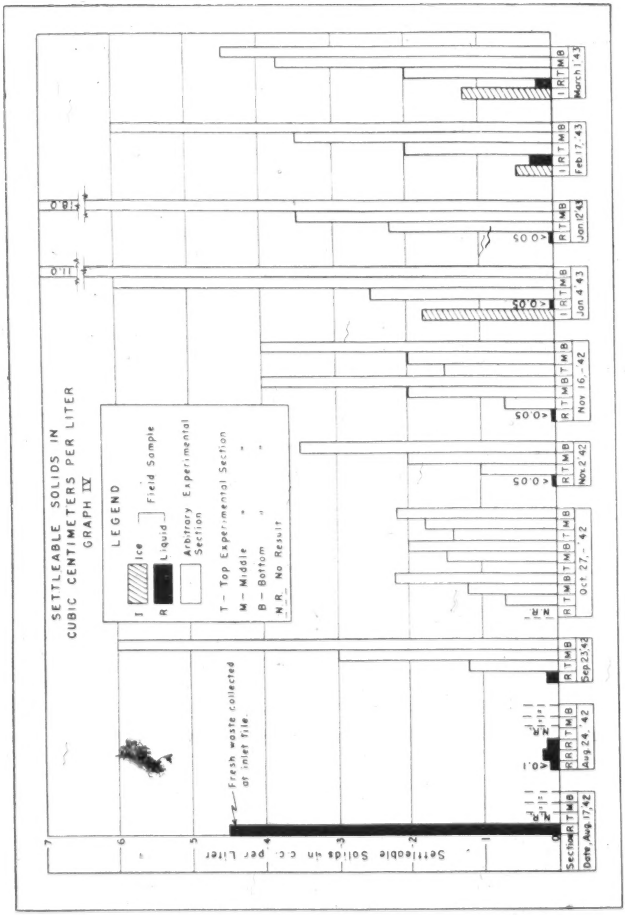
(GRAPH I)


TOTAL SOLIDS IN
PARTS PER MILLION
GRAPH II
LEGEND
I Ice
R Liquid
Field Samples
Arbitrary Experimental Section
T - Top Experimental Section
M - Middle "
B - Bottom "
N.R. No Result
Total Solids in p.p.m.
14,000
12,000
10,000
8,000
6,000
4,000
2,000
0
Section R T M B
Date Aug. 17, 42
Aug. 24, 42
Sep. 23, 42
Oct. 27, 42
Nov. 2, 42
Nov. 16, 42
Jan. 4, 43
Jan. 12, 43
Feb. 17, 43
March 1, 43

(GRAPH II)

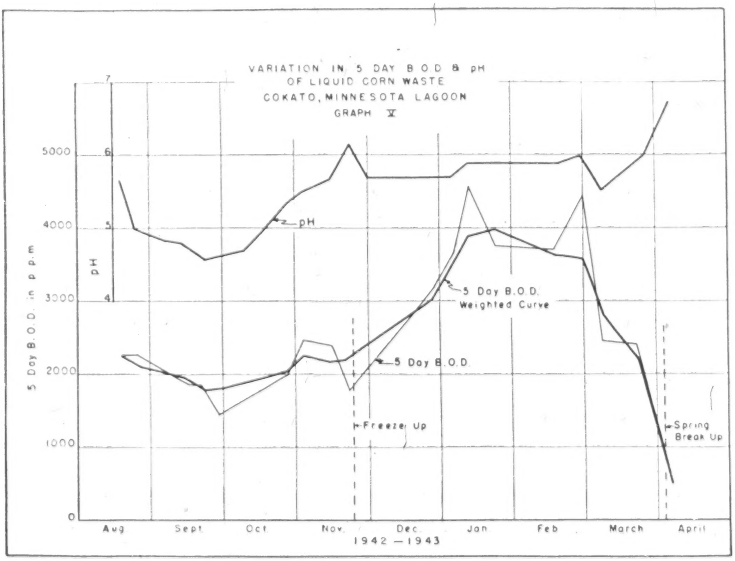

TOTAL SUSPENDED SOLIDS IN PARTS PER MILLION
GRAPH III
LEGEND
I Ice
R Liquid
Field Samples
Arbitrary Experimental Section
T Top Experimental Section
M Middle " "
B. Bottom " "
N.R. No Result
Total Suspended Solids in p.p.m.
0
100
200
300
400
500
600
900
770
2230
1180
Section R T M B
Date Aug 17, '42
Aug 24, '42
Sep 23 '42
Oct 27, '42
Nov 2, '42
Nov 16, '42
Jan 4, '43
Jan 12 '43
Feb 17, '43
March 1, '43

(Graph III)


SETTLEABLE SOLIDS IN
CUBIC CENTIMETERS PER LITER
GRAPH IV
LEGEND
I Ice
R Liquid
Field Sample
Arbitrary Experimental Section
T - Top Experimental Section
M - Middle " "
B - Bottom " "
N.R. No Result
Fresh waste collected at inlet tile.
Settleable Solids in c.c. per Liter
Section
Date, Aug. 17, '42
Aug. 24, '42
Sep. 23, '42
Oct. 27, '42
Nov. 2, '42
Nov. 16, '42
Jan. 4, '43
Jan. 12, '43
Feb. 17, '43
March 1, '43
11.0
18.0
<0.05
<0.1

(GRAPH IV)

Graph V shows the variation in strength of the liquid waste for the entire holding period in the Cokato lagoon as measured by the five-day biochemical oxygen demand test. The curve has been weighted to suppress individual results (Table III).



(GRAPH V)

The Effect of Freezing Upon Solids

It seems probable that two different changes take place during the freezing process. The first and most obvious change is the "freezing out" of solids from true solution. By this physico-chemical process, concentration is well marked and definitely established. Yet, this change alone does not explain the appreciable increases in settleable solids in all layers (see Figure 3). If the tendency for the solvent to crystallize in the pure state were the only process involved, it would hardly be expected that there would be such large increases in settleable solids in the top layer accompanying an equally large drop in total solids in the same layer. Therefore, by a negative approach, it appears quite probable that another change takes place in the ice itself. While it was not the purpose of these studies to make extensive investigations of all the mechanisms involved, it does seem that some colloidal modification takes place. Cannery waste, in general, tends to be highly colloidal and contains a lyophilic hydrosol (*i.e.*, a readily precipitated colloid in a water solution). This lyophilic system consists of organic vegetable particles containing a high percentage of the dispersions medium or water. On the basis of the data obtained, it seems reasonable to con-

clude that the freezing of these lyophilic colloidal particles causes a separation of some of the dispersions medium and results in the production of settleable solids.

In order to effect a reduction in biochemical oxygen demand, the changes in solids distribution and the state of the solids must be such that they tend to settle rapidly. In addition, once they have been forced out of solution or out of the colloidal state, as the case may be, they must not be easily returned to solution. This has been borne out by the experimental evidence. Graph IV shows clearly that the settleable solids are increased many-fold by the process of freezing. A careful examination of this bar diagram will show that in many cases the settleable solids are increased 10,000 per cent or more. Likewise, ice samples from the lagoon showed very large increases in settleable solids.

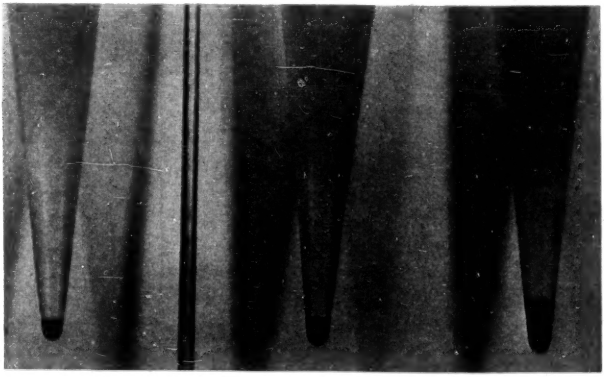


FIG. 3.—Typical settleable solids determination. Top, middle and bottom, from left to right.

In all instances, however, the ice samples from the lagoon showed lesser gain in settleable solids than did samples frozen under laboratory conditions. This can possibly be explained by the fact that the rate of freezing was much less under natural conditions, resulting in a much purer solvent crystal structure (more free from occluded solids). This is also borne out by Graph I which shows that the five-day biochemical oxygen demand of the ice samples from the lagoon was always less than that of the top layer of ice from an experimental sample (see also results on ice samples from the lagoon, Graph II). The physical nature of the settleable solids is also a matter of interest. Though no actual tests were made to determine the rate of settling, it is certain that 75 per cent of the settleable solids were collected within one-half hour.

Return of Solids to Solution

One test was made to determine semi-quantitatively the tendency of precipitated solids to go back into solution on the melting of the ice. A slurry of bottom sediment from a melted laboratory sample was thor-

oughly mixed with distilled water. The ratio of slurry to distilled water was 1:10. A portion of the resultant mixture was again diluted 1:10 with distilled water and thoroughly mixed. Each was then set aside for 24 hours at room temperature. At the end of 24 hours the slurry, the dilution 1:10, and the dilution 1:100 were tested for total solids, total volatile matter, total suspended solids and total suspended volatile matter. On the fair assumption that the total solids should not change, they can be used as a basis for computing the experimental error of this procedure. Since the primary interest is the solids, not

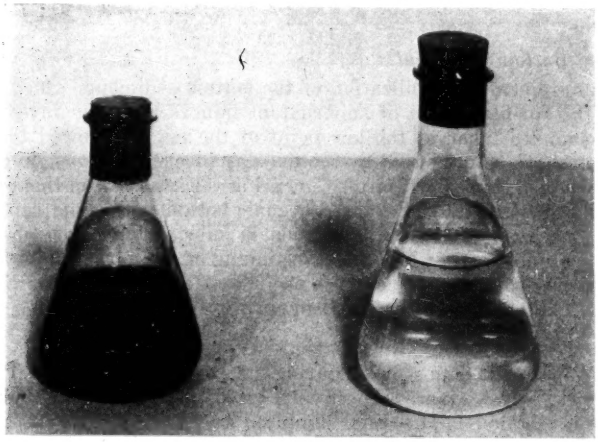


FIG. 4.—Frozen sample after melting. Sediment at left; supernatant at right.

in true solution or colloidal state, an examination of suspended solids should form the basis for any conclusions. Using total solids as an indication of error, it was found that the total suspended solids or total suspended volatile matter determination must be corrected by 5 per cent in the first dilution, 13.4 per cent in the second, and overall between slurry and dilution 1:100 by 15 per cent. The total suspended solids showed a decrease of 13.8 per cent in the first dilution, about 17.8 per cent in the second, or 28.4 per cent overall, while the total suspended volatile matter showed corresponding decreases of 5.3 per cent, 15.7 per cent and 21.0 per cent. Therefore, after applying the correction as determined from the total solids determination, about 13 to 14 per cent of the total suspended solids were returned to solution overall, while only 6 per cent of the total suspended volatile matter was returned to solution in a dilution of 1:100. It is highly unlikely that under natural conditions these ratios would hold valid. It appears that under natural conditions a smaller portion of total suspended solids could be expected to go back into solution. The above is not offered as positive proof that a relatively small portion will return to solution on melting, but rather as the results from a single test, the conclusion being subject to neces-

sary modification when further evidence is available. Attention is also called to Figure 4. The clear supernatant liquor in the flask has remained clear. The sediment in the sediment flask settles out in a dense layer approximately one-half inch thick in the bottom of the flask. Thorough shaking will quickly cloud the liquid in the sediment flask; however, on standing one hour, the sediment has again settled out in a dense layer of undiminished volume in the bottom of the flask. This test has been repeated many times during the past seven months, and confirms the aforementioned test, *i.e.*, that once the solids are thrown out by freezing, little if any of the precipitated matter returns to solution.

Lagoon Bottom Sediments

The problem of stabilization of the bottom sediments which remain after the spring release of supernatant liquors has been investigated. Field samples taken at the low point of the lagoon showed that very little strength as measured by the five-day biochemical oxygen demand test remained three weeks after the spring release. From this evidence it would appear that the exposed organic bottom sediments rapidly become stabilized, and that the lagoon is substantially free of decomposable organic matter before the beginning of the next canning season. There was about one-sixteenth of an inch of dry sediment on the floor of the Cokato lagoon after the 1943 spring release.

Analytical Data

The analytical data secured during the studies are shown in Tables I, II and III, which cover, respectively, biochemical oxygen demand, solids determinations and special samples.

TABLE I.—*Analytical Data. Freezing as a Factor in the Stabilization of Corn Cannery Waste. Biochemical Oxygen Demand and pH*

Date Sample Collected	5-Day B.O.D. (p.p.m.)					10-Day B.O.D. (p.p.m.)					pH				
	Lagoon Sample		Sample Frozen in Laboratory			Lagoon Sample		Sample Frozen in Laboratory			Lagoon Sample		Sample Frozen in Laboratory		
	Liquid	Ice	Top	Middle	Bottom	Liquid	Ice	Top	Middle	Bottom	Liquid	Ice	Top	Middle	Bottom
8/17/42	2230		1040	1920	6300	2910		990	1990		5.65		4.2	4.2	4.5
8/24/42	1110 1090 2240		740	1830	2590	1100 1350 3450		770	2030	3180	5.0 5.0 3.95				
9/22/42	1840		730	2120	4980	2430		1720	3010		4.6				
10/27/42	1990		560 1010	1920	3700 4810	2010		1340 1330	2130 2490 1870	6760	5.35		5.47 5.55 5.5	5.5 5.55 5.5	5.65 5.65 5.6
11/ 2/42	2470		410					1760	1950	4440	5.5		5.55	5.6	5.6
11/16/42	2380		860 880	2440 2510	7700 6070	2400		950 1100	2550 3040	8580 3750	5.65		5.65 5.85	5.8 5.75	5.85 5.85
1/ 4/43	3630	650	1550	4020	13,700	4840		1640					5.7	5.7	5.75	5.7	5.7
1/12/43	4580		1785	3020	10,930			2280	3350	12,820	5.9		6.05	5.9	5.8
2/17/43	3720	180	1590	3420	10,900	4160	220	1540	4440	13,800	5.9	6.0	6.0	5.9	5.7
3/ 1/43	4450	660	1660	3110	10,500	4990	810	3140	4060	11,200	6.00	6.35	6.0	6.0	6.0

TABLE II.—*Analytical Data. Freezing as a Factor in the Stabilization of Corn Cannery Waste. Solids Determinations*

Date Sample Collected	Total Solids (p.p.m.)					Total Volatile Matter (p.p.m.)					Suspended Solids (p.p.m.)					Total Suspended Volatile Matter (p.p.m.)					Settleable Solids (c.c. per liter)				
	Lagoon Sample		Sample Frozen in Laboratory			Lagoon Sample		Sample Frozen in Laboratory			Lagoon Sample		Sample Frozen in Laboratory			Lagoon Sample		Sample Frozen in Laboratory			Lagoon Sample		Sample Frozen in Laboratory		
	Liquid	Ice	Top	Middle	Bottom	Liquid	Ice	Top	Middle	Bottom	Liquid	Ice	Top	Middle	Bottom	Liquid	Ice	Top	Middle	Bottom	Liquid	Ice	Top	Middle	Bottom
8/17/42	2950		1220	2410	8460						900		300	770	2330						4.5				
8/24/42	1370		700	1770	2620	770		410	960	1350	27		46	83	150			43	69	120	<0.1				
	1370					810					25										0.2				
	4330					3720					1180										15.0				
9/22/42			965	1820	450								115	145	270			115	140	180	0.15		1.2	3.0	6.0
10/27/42			1075	1790	4570			675	1030	2590			120	150	275			103	122	170			0.7	1.2	2.2
			1270	2060	4210			795	1185	2350			135	160	230			109	117	160			1.0	1.5	2.0
			875	1930	5370			590	1100	2925			115	130	225			90	110	160			1.4	1.8	2.2
11/ 2/42	1720		1115	1410	4355	970		870	1040	2410	100		135	150	230	95		97	97	137	<0.05		1.0	2.0	3.5
11/16/42	1750		730	1965	6555	1017		430	1080	3120	27.3		110	130	225	22		81	84	138	<0.05		0.7	2.0	4.0
			915	2255	5430			580	1340	2940			117	133	220			89	98	130			1.5	2.0	4.0
1/ 4/43	3080	760	1230	3290	10.760	1700	450	730	1810	5860	83	170	149	210	524	60	110	96	125	232	<0.05	1.8	2.5	6.0	11.0
1/12/43	3050		1610	2460	10.100	1640		900	1335	5385	138		164	144	490	102		106	86	178	<0.05		2.2	3.5	18.0
2/17/43	3310	310	1220	3430	9900	1860	195	700	1935	5530	104	44	160	240	390	70	42	100	140	190	0.3	0.5	2.0	3.5	6.0
3/ 1/43	3300	640	1740	3040	9300	1800	350	1000	1670	5220	105	100	155	165	315	60	58	87	87	130	0.2	1.2	2.0	3.5	4.5

TABLE III.—*Analytical Data. Freezing as a Factor in the Stabilization of Corn Cannery Waste. Special Samples*

Set No.	Date	5-Day B.O.D.	10-Day B.O.D.	pH	Susp. Solids	Total Solids	Total Vol. Matter	Total Susp. Solids	Total Susp. Vol. Matter	Explanations
1	12/ 2/42	>22,000	—	5.9	*	27,160	11,750	1200	450	Approximately 150 ml. from cone bottom (frozen sample).
2	1/ 4/43	3630	4840	5.7	<0.05	3080	1700	83	60	Liquid from lagoon.
		3690	4650	—	4.5	3320	1840	200	130	Liquid from lagoon, frozen, melted and mixed.
3	2/ 4/43	25,900	31,700	5.9	*	31,000	17,790	1720	690	Original frozen, melted, settled and sediment drawn off bottom of cone.
4	3/ 1/43	>1560	—	6.2	<0.05	1450	820	18.5	12	Original frozen, melted, settled and 2 liters supernatant drawn off top. (Sample A.)
		10,700	16,000	6.2	*	18,820	10,210	10,620	5070	Bottom sediment of Sample A (200 ml.). (Sample B.)
		—	—	6.25	*	1790	900	915	48	Portion of Sample B diluted 1:10 and well mixed.
		—	—	6.35	*	155	58	76	40	Portion of Sample B diluted 1:100 and well mixed.
5	3/ 8/43	2460	5310	5.5	0.5	3900	2160	140	90	Liquid from lagoon.
		480	630	6.0	0.2	530	405	50	32	Ice from lagoon (lower layer).
6	3/25/43	2400	2830	6.0	1.2	2360	1330	125	80	Liquid from lagoon.
		330	370	6.5	3.5	656	365	310	130	Ice from lagoon (lower layer). See discussion of Sample C (snow not included.)
		200	290	6.5	3.2	670	350	220	125	Field sample, liquid frozen at lagoon under natural conditions including weathering. Includes snow coverage. (Sample C.)
7	3/ 9/43	3200	—	6.5	0.7	3400	2110	56	16	Original frozen, melted, settled and 2 liters supernatant drawn off top.
		9100	9800	6.1	*	22,140	10,050	16,120	6120	Original frozen, melted, settled and sediment drawn off bottom of cone.
10	4/ 6/43	460	—	6.75	<0.1	380	55	350	55	After spring break-up; includes dilution of waste due to snow.

* No result, volume too small.
All results in parts per million.

Comments on Lagoon Design

To obtain full advantage from the effect of freezing in the stabilization of lagooned corn wastes, considerable thought should be given to details of construction and operation of the lagoon. A broad, shallow lagoon will make possible the freezing of a larger portion of the waste. This same construction affords more favorable conditions for the penetration of sunlight and presents a greater surface area for reaeration by contact and wind action during the period when there is no ice coverage. Odor control by the addition of sodium nitrate solutions has also proven more effective in broad, shallow lagoons. Bottom slopes should be very gentle, and channels may be required to conduct stabilized waste to the point of discharge with a minimum agitation of bottom sediments. To eliminate high velocities, outlet works should be constructed to collect at the surface over a long weir length. A floating discharge weir which automatically follows the receding supernatant liquors may be one solution.

Summary and Conclusions

The experimental evidence and field data obtained thus far appear to indicate that freezing is an important factor in the stabilization of lagooned corn canning waste.

As a result of the tendency of the water vehicle to crystallize in the pure state and some other physico-chemical process that takes place in the ice itself, solids are thrown out of solution and suspension and precipitated out as bottom sediments.

The evidence indicates that only a small fraction of the precipitated solids will go back into solution.

On melting isolated frozen samples, the experiments have shown that the settleable solids may be increased as much as 10,000 per cent over the settleable solids found in the original unfrozen sample.

The solids thrown out of solution settle rapidly, leaving a relatively clear supernatant liquor. Inasmuch as the strength of the waste is contained in the organic solids in solution or suspension, a reduction in these solids reduces the biochemical oxygen demand of the supernatant liquors which are discharged to receiving waters.

Broad shallow lagoons make possible the freezing of a larger portion of the waste, afford more favorable conditions for the penetration of sunlight, and present a greater surface area for reaeration by contact and wind action during periods when there is no ice coverage.

It is possible that wider application of the freezing effect may be made in northern latitudes, as a factor of perhaps equal importance to biological action and aeration, in the stabilization of other wastes impounded in broad shallow lagoons for stabilization by such timed treatment processes.

Research

EFFECT OF POLYSULFIDE TREATED CYANIDE CASE HARDENING, COPPER AND ZINC PLATING WASTES ON SLUDGE DIGESTION

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A report (1) has been given on laboratory studies of the effect of lime-sulfur-treated cyanide case hardening, copper and zinc plating wastes on the aerobic biological units of sewage purification as represented by the activated sludge type of treatment. In general the aerobic processes of sewage treatment are expected to be most greatly affected by toxic substances introduced in the sewage, since the bulk of the material passes through that part of the plant. A portion of these substances, however, may also be expected to reach the sludge digestion units with the solids removed from sedimentation tanks in an amount approximately proportionate to the volume of sludge transferred to the digesters. The proportionate part of industrial wastes thus reaching the digesters is usually small. Should the toxicity of the wastes be sufficiently high, however, relatively small quantities might interfere with the anaerobic digestion process. The studies reported herein represent further laboratory investigations of the effect of the lime-sulfur treated cyanide carburizing solution wastes from the case hardening process and the treated copper and zinc cyanide solution wastes from the electroplating process on the anaerobic sludge digestion process in sewage treatment.

Method of Investigation

The apparatus used for these studies consisted of twenty-four individual laboratory digestion and gas collection units designed to provide separate sludge digestion and gas measurement at atmospheric pressure. The construction and arrangements of these units is shown in Figures 1 and 2.

The studies were divided into three separate phases:

(1) the effect of varying amounts of the carburizing, zinc and copper plating wastes on the batch digestion of sludge;
(2) the effect of daily additions of the wastes in various amounts

* Assisted in study as part of graduate work in School of Public Health, University of Michigan, Ann Arbor, Michigan.

on digestion with daily additions of fresh sludge, referred to as continuous digestion;

(3) the effect of daily additions of the principal constituents of the wastes, namely, sodium cyanide, sodium thiocyanate and calcium polysulfides, on digestion with daily additions of fresh sludge.

The ripe sludge used for seeding and the fresh sludge used in charging the digesters were obtained from the Ann Arbor sewage treatment plant. Solids in the ripe sludge were 2.87 per cent and volatile matter 60 per cent. The fresh sludge was 3.2 per cent solids and volatile matter 80 per cent. For the batch process of operation, the charge of fresh solids to ripe sludge was in the ratio of 1 gram of volatile matter to 20 grams of digested sludge on the dry weight basis. In the continuous digestion studies, daily additions of fresh solids were maintained throughout the experiment in the ratio of 0.20 grams of fresh solids volatile matter to 15 grams of initial digested sludge.

The wastes were added to the digesters in increments between the following equivalent ratios:

	Actual Amount Waste Added to Digesters		
	Parts per Million (wet sludge basis)	Milligrams of Waste Solution per Gram of Digester Sludge (dry basis)	Gallons of Waste per 1,000 cu. ft. of Digester Capacity
Batch Digestion with Waste Solutions		Initial Addition	
Carburizing waste solution	0–15,000	0–523	0–112
Zinc plating waste solution	0– 5,000	0–174	0– 37
Copper plating waste solution	0– 5,000	0–174	0– 37
Continuous Digestion with Waste Solutions		Daily Addition	
Carburizing waste solution	0– 2,100	0– 73	0– 15
Zinc plating waste solution	0– 1,800	0– 62	0– 13
Copper plating waste solution	0– 2,100	0– 73	0– 15
Continuous Digestion with Basic Waste Constituents		Daily Addition	
Sodium cyanide	0– 30	0–0.10	
Sodium thiocyanate	3– 250	0–0.87	
Calcium polysulfide solution	0– 150	0–0.50	

The analyses of the added lime-sulfur treated waste solutions were as follows:

	Carburizing Salt Bath Waste Solution	Copper Plating Waste Solution	Zinc Plating Waste Solution
NaCNS, p.p.m.	50,000	80,000	74,000
NaCN, p.p.m.	210	300	140
Calcium polysulfide, p.p.m.	excess	excess	excess

In the batch digestion tests, 54 ml. of fresh sludge were added to and thoroughly mixed with 926 ml. of the digested sludge in each digester bottle. The different quantities of wastes were added and mixed at this same time. The digestion gas collection units were connected with the gas measuring chambers and nitrogen gas bubbled through the whole apparatus to sweep out atmospheric gases. The nitrogen gas was then displaced from the gas chamber by acidified water. Gas measurements were taken daily for rate and volume production, and the gas analyzed for CO_2 and H_2S at frequent intervals during the entire digestion period.

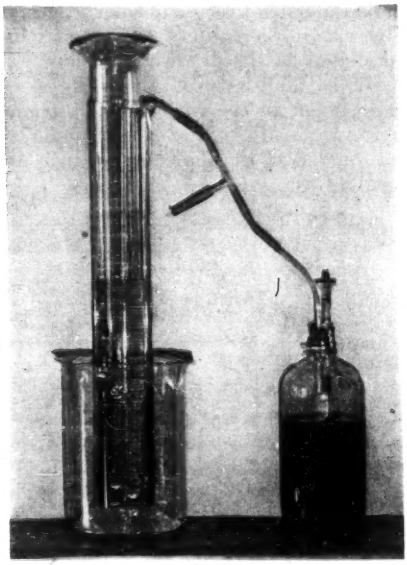

FIG. 1.—Detail of sludge digestion and gas collection apparatus.

The continuous digestion studies in which raw sludge and wastes were added daily, were conducted in a manner similar to that of the batch digestion with the exception that all raw sludge added was screened through a 10-mesh screen to obtain uniformity. The sludge was added through a long stem, large bore, small flanged funnel passing through the same stopper containing the gas delivery outlet from the sludge digestion bottle. This same inlet was used to collect samples for analysis of sludge for pH, per cent solids and volatile matter. The collected gas was analyzed for H_2S and CO_2 by exhausting into 500 ml. erlenmeyer flasks with a service vacuum line. These flasks contained 50 ml. of 0.1 N sodium hydroxide, carbonate free. Two hundred ml. of gas was then taken from the units by way of the side arm on the de-

livery tube, the volume being indicated by the difference in readings on the inverted graduate. The flasks were clamped, shaken vigorously several times and after standing 15 minutes in the cold, titrated, first with standard H_2SO_4 to phenolphthalein and then with iodine solution using starch iodide as an indicator. Further titrations of the samples were made with standard acid to methyl-orange as a means of checking alkalinity.

In the continuous digestion studies in the presence of basic constituents of the wastes the same procedure was followed, except that certain variations in daily rate of additions of the chemicals were made as was indicated to be advisable by the course of digestion. These variations are given in the data.

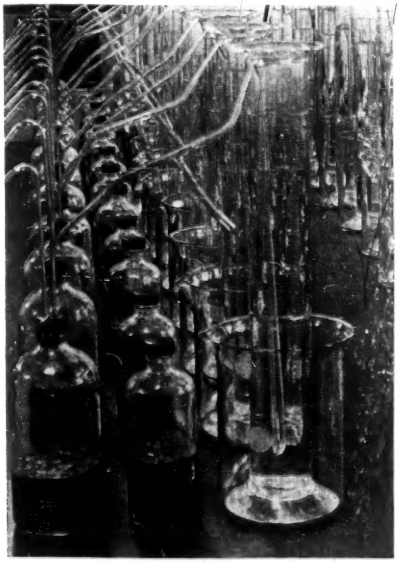

Fig. 2.—Arrangement of sludge digestion and gas collection units.

Results

The results of the studies are given in Figures 3 to 7.

Batch digestion data are presented in Figure 3, plotted to show accumulated gas produced over a thirty-day digestion period in the presence of varying concentrations of the carburizing, copper and zinc plating waste solutions. The control consisted of three units which were treated exactly as those units receiving the wastes with the exception that no wastes were added. These three controls were used to give the maximum and minimum experimental error values. The hatched curves

in the figures are plotted from these maximum and minimum values. The gas production of any unit falling between these values of the control was considered as unaffected by the waste as far as quantity of gas is concerned.

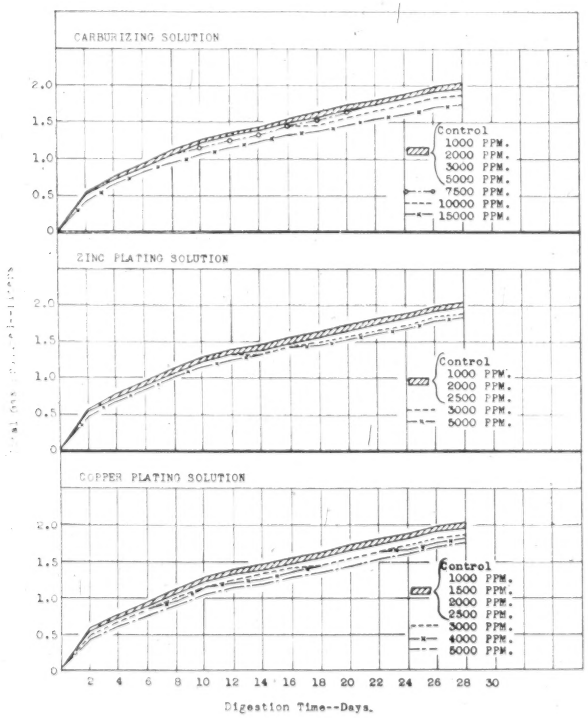

FIG. 3.—Effect of batch addition of carburizing and plating waste solutions.

The data on continuous digestion in the presence of different concentrations of waste solutions and basic waste constituents are likewise plotted in Figures 4 and 5. The concentrations of wastes noted in the figures are the quantities added daily. In Figure 5 the rate of addition of certain wastes was changed during the digestion period. The amount of change is indicated by a multiple of the original concentration, *e.g.*, in the curve for sodium thiocyanate, one curve shows the addition of 50 p.p.m. at the start of the experiment. On the ninth day, however, the charge of waste in this digestion was changed to $2x$ or $2 \times 50 = 100$ p.p.m., etc.

Figure 6 gives the relation of total gas produced over the entire digestion period to the concentration of wastes. The values for sodium

cyanide are not given, however, because of the difficulty of plotting the changes in the rate of additions of cyanide during the digestion period.

The proportion of hydrogen sulfide in the digestion gas, in per cent, is plotted against varying concentrations of the wastes as presented in Figure 7.

Discussion of Results

In both investigation and interpretation of the results attention has been directed to (1) maximum quantity of any one specific waste or

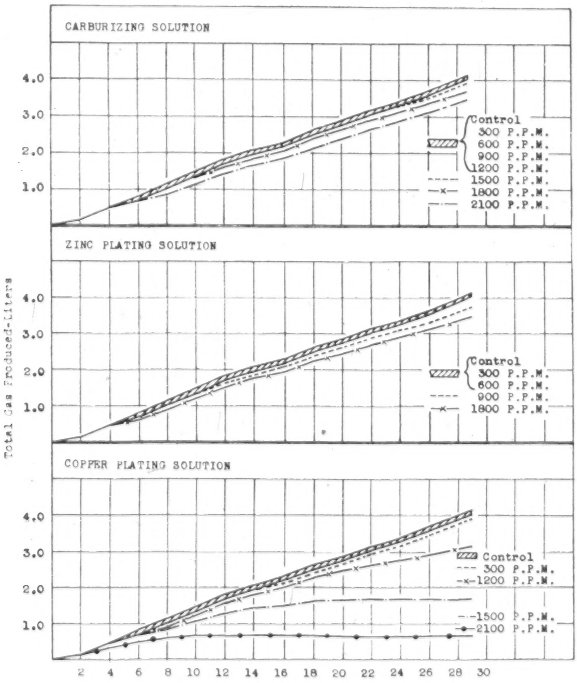

Fig. 4.—Effect of daily additions of carburizing and plating waste solutions.

basic waste constituent that could be added to the digester before the rate of digestion as measured by gas production was retarded, (2) the extent of retardation by this same index, and (3) the effect on the quality of gas with respect to carbon dioxide and hydrogen sulfide content, the former serving as an indirect measure of the affect on heating value of the gas, and the latter as indicating a change in corrosive qualities of the gas. With this in mind an inspection of the curves shows the following:

Carburizing Solution

In the batch addition process, Figure 3, concentrations of carburizing waste solution up to and including 7,500 p.p.m. did not affect the rate of gas production. Beyond that concentration both rate and total quantity of gas was reduced, though there did not seem to be any point up to 15,000 p.p.m. where definite critical toxicity was indicated. Increased concentrations merely depressed both rate and total quantity of gas produced.

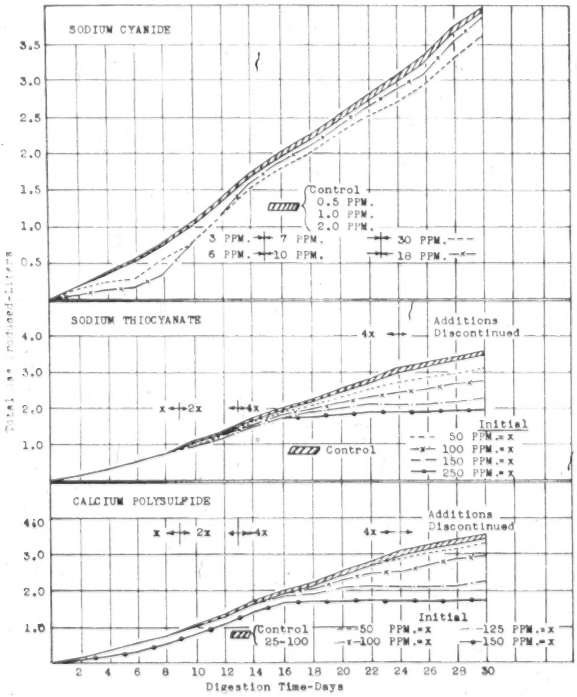

FIG. 5.—Effect of daily additions of NaCN, NaCNS, and CaS.

In the case of continuous daily additions, waste charges up to and including 1,200 p.p.m. were tolerated without significant effect on digestion. Beyond this amount the rate and quantity of gas decreased, somewhat in proportion to the amount of waste added above the 1,200 p.p.m. level.

With respect to quality of gas produced, none of the charges studied showed any effect on the carbon dioxide-total gas ratio. As shown in Figure 7, however, the hydrogen sulfide content of the gas increased

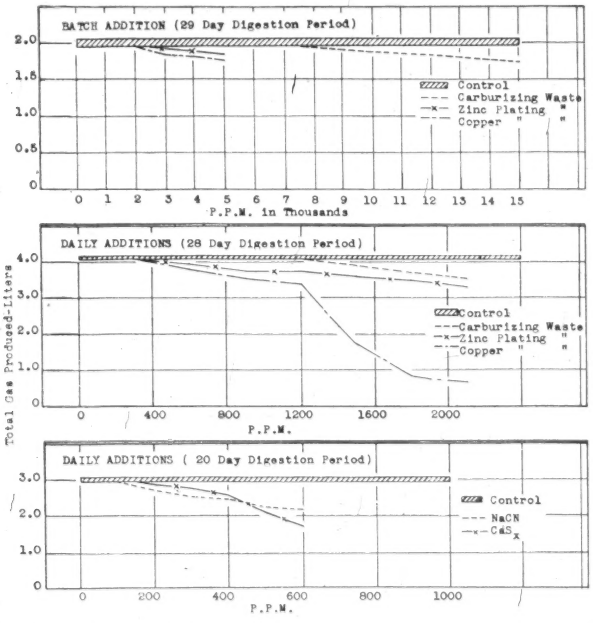

FIG. 6.—Effect of waste solutions and basic waste constituents on total gas production.

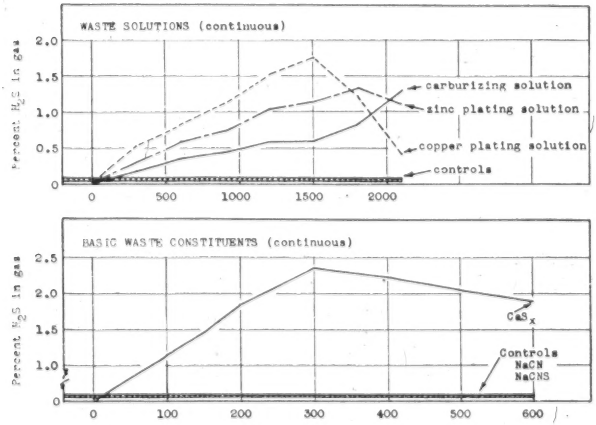

FIG. 7.—Hydrogen sulfide produced in digestion gas from waste solutions and basic waste constituents.

somewhat in proportion to the amount of waste added, reaching a final concentration of 1.3 per cent in the presence of a daily addition of 2,100 p.p.m. of carburizing solution.

Zinc Plating Solution

The zinc plating solution, in the batch process, showed digestion tolerance of the waste up to and including 2,500 p.p.m. before rate or quantity of gas produced decreased. Beyond that point both were reduced with no critical limit indicated up to 5,000 p.p.m.

In the case of continuous daily additions a charge of over 600 p.p.m. was necessary before the gas production was affected.

With the exception of the proportion of H_2S, the gas quality was relatively unaffected by any of the wastes concentrations studied. Here, as in the previous instance, the H_2S increased in proportion to the amount of waste added up to a critical value of 1.35 per cent with the addition of 1,800 p.p.m. of the waste (Figure 7). Increased concentration of waste beyond this point reduced the proportion of the H_2S in the gas to 1.15 per cent at a charge of 2,100 p.p.m. of the waste. Apparently the latter concentration of the waste critically effected the H_2S producers.

Copper Plating Solution

Quantity and rate of gas production decreased in batch digestion in the presence of the copper plating solution at about the same charge as the zinc solution, namely, above 2,500 p.p.m. Increased quantities of the waste above this value also more or less proportionately decreased the gas quantity and rate with no critical effect up to 5,000 p.p.m.

In the case of daily addition of fresh sludge, Figure 3, a daily charge of less than 300 p.p.m. reduced the rate of gas produced after the fourteenth day of digestion. Increased quantities of the waste above this value depressed digestion activity quite materially until at 2,100 p.p.m. activity practically ceased. The toxicity of probable copper residuals in the waste was indicated in this test.

As to quality of gas, no measurable difference was observed in the ratio of CO_2 to total gas. However, as shown in Figure 7, the per cent H_2S increased quite sharply up to 1.75 per cent at a charge of 1,500 p.p.m. Increased charges beyond this point sharply decreased the proportion of H_2S. It is to be noted that this is about the critical point at which digestion was practically completely retarded. It appears, however, that the sulfide producers had greater tolerance to the waste than the other organisms engaged in digestion since up to the critical value, the proportion of H_2S increased quite sharply. At the higher concentration the pH also decreased quite sharply, indicating the greater resistance of the acid formers to the waste.

Sodium Cyanide

The effect on digestion of sodium cyanide, one of the residual constituents of the treated carburizing and plating wastes, is shown in Fig-

ure 5. Some specifically interesting results are shown in the data on this material. The limit of tolerance of the waste when first introduced was low. All units receiving waste charges below 2.0 p.p.m. daily gave results in gas production corresponding to the three controls. Initial daily charges of 3 p.p.m. and above, however, retarded gas production quite effectively until the sixth day whereupon the rate of production increased above that of the controls. At the end of the fourteenth day total gas produced almost reached the total of the controls, in spite of the constant daily charges of NaCN up to 6 p.p.m. On the fifteenth day the sodium cyanide addition was increased to 10 p.p.m. daily with but slight effect on digestion. On the twenty-third day charges of the cyanide were increased to 30 p.p.m. daily. Even this charge failed to reduce materially the rate of gas production during the remainder of the experiment. It thus seems evident that the acclimatization of the sludge to the cyanide quickly occurs after the first charge shock, presumably through development of anaerobic cyanide decomposing organisms. This same tendency was shown in the previous work on these wastes (1) under the aerobic process of activated sludge, where increased additions of the cyanide failed to destroy purification activities completely, indicating that a waste tolerance was being built up in the sludge.

The gas quality was practically unaffected by the sodium cyanide as shown in Figure 7. Both CO_2 and H_2S in the gas were within the limits of the controls.

Sodium Thiocyanate

The daily charges of sodium thiocyanate showed no effect on gas production up to 250 p.p.m. at the end of a nine-day period (Figure 5). Doubling these amounts showed slightly increased effects, particularly at 500 p.p.m. At the end of thirteen days the charges were quadrupled. Thereafter, the effect was pronounced, being in rough proportion to the amount of the substance added.

Quality of the gas was unaffected up to 600 p.p.m. (Figure 7).

Calcium Polysulfide

Calcium polysulfide gave evidence of affecting digestion at a point between 100 and 200 p.p.m. At 400 p.p.m. digestion was retarded to a considerable extent, and at 500 p.p.m. digestion practically ceased.

The effect on gas quality is shown by the H_2S in the digester gas formed, which increased to 2.3 per cent with the daily addition of 300 p.p.m. of the material. With further increase in charge the percentage of H_2S in the gas decreased due to increased toxicity of the polysulfide for the H_2S producers.

Relative Effects of the Waste Materials on Gas Production

The relative effects of all the wastes on total gas produced in comparable digestion periods are shown in Figure 6. The data in this fig-

ure indicate that in general a material concentration of any one waste can accompany digestion without reducing the total gas. Above this concentration, total gas from digestion decreases for each waste as more or less of a straight line function, up to the maximum concentration studied. The exception to this was the copper plating solution which at 1,200 p.p.m. exerted a greatly increased toxic effect, presumably due to residual copper in the solution. It is also at about this same charge (above 1,500 p.p.m.) that H_2S in the digestion gas began to decrease quite rapidly, probably due to the same cause.

General Discussion

From these data it appears that as far as total quantity and rate of gas production is concerned, a material concentration of each of the polysulfide treated waste solutions as discharged from industry can be tolerated in sludge digesters operating under normal loading conditions. The tolerance level is more or less specific for each waste and depends on the manner in which the wastes are added. In this study these levels are summarized as follows:

	Daily Addition with Continuous Digestion
Carburizing solution	1,200 p.p.m.
Zinc plating solution	600 p.p.m.
Copper plating solution	200 p.p.m.

In case of a single batch charge of the wastes representing a sudden and unexpected large discharge from the industry, the tolerance levels of charge before quantity gas production was affected were:

Carburizing solution	7,000 p.p.m.
Zinc plating solution	2,500 p.p.m.
Copper plating solution	2,000 p.p.m.

Of the basic constituents of the various wastes, the sodium thiocyanate and calcium polysulfide appeared to be equally toxic and the influence of these substances in causing decreased gas production occurred before the residual quantities of NaCN, copper and zinc increased by the waste treatment became significant. In fact, the digestion process demonstrated acclimatization to at least small quantities of the sodium cyanide. It thus appears that the concentration of the calcium polysulfide and sodium cyanide in the waste solutions is the major factor in hindering digestion.

The most significant influence of the wastes on quality of digester gas appeared to be in the increased proportion of H_2S. The quantity of this gas seemed to be solely related to the polysulfide in the wastes. At the tolerance concentration level of the various wastes the H_2S content of the digester gas appeared as follows:

	Maximum Before Gas Quantity Decreased	Per Cent H_2S in Digester Gas
Carburizing solution	1,200 p.p.m.	1.5
Zinc plating solution	600 p.p.m.	0.6
Copper plating solution	200 p.p.m.	0.15

In general, it would appear from these studies that the sludge digestion units of a sewage treatment plant would, except under unusual conditions, be relatively unaffected by the discharge of these plating wastes to the sewerage system of a normal community. Taking into account the combined effect of sewage dilution in the sewerage system and the relatively small proportion of the sewage liquid that reaches the digesters, the quantity of treated wastes discharged from the industry would have to be exceedingly large before sludge digestion would be affected. For instance, assuming a sludge volume-sewage flow ratio of 50 to 1, the concentration of carburizing solution could reach 60,000 p.p.m. in the raw sewage before digestion would be affected. This is equivalent to a waste solution discharge into the sewage flow of 450 gallons per 1,000 cu. ft. of sludge digestion capacity. Likewise, the zinc plating and copper plating waste solution concentration in the sewage could be as high as 30,000 and 10,000 p.p.m., respectively, equivalent to a discharge of 225 and 75 gallons of the waste solutions per 1,000 cu. ft. sludge digestion capacity. Only in unusual circumstances, where the ratio of waste to sewage was exceedingly high, would it seem to be expected that the waste solutions used in this study would be an important factor in sludge digestion tank operation.

Summary

The effect of polysulfide treated case hardening, copper and zinc plating solutions on sewage sludge digestion was investigated in the laboratory. Rate and quantity of gas produced from the digesters was used as the index of waste toxicity. In addition, the effect of the wastes on gas quality was determined by the CO_2 and H_2S contents of the digester gas.

The data indicated that a material concentration of each of the wastes could be tolerated by the sludge digestion process before digestion was impaired, varying from daily additions of 200 p.p.m. for the copper plating solution to 1,200 p.p.m. for the carburizing solution. In single batch charges of the wastes the tolerance level was from 2,000 p.p.m. for the copper plating solution to 7,000 p.p.m. for the carburizing solution. The indicated factor of toxicity was either or both the calcium polysulfide and sodium thiocyanate, both basic constituents of the treated wastes. Sodium cyanide in initial charges was toxic even at 3.0 p.p.m., but acclimatization of the digesting sludge allowed greatly increased doses (up to and beyond 30 p.p.m.) before digestion was materially impaired.

All wastes increased the H_2S content of the digester gas. The causative agent for the increased proportion of H_2S was the calcium polysulfide, a basic constituent of each waste. At the maximum tolerance level of the waste for digestion, the H_2S in the digester gas was 0.15 per cent for the copper plating solution, 0.6 per cent for zinc plating solution and 1.5 per cent for the carburizing solution.

Only in unusual circumstances, however, where the ratio of volume of waste discharge to sewage flow is large, would it be expected that

sludge digestion tank operation would be affected. This is due to the combined effect of dilution of the wastes by the sewage and the small proportionate part of the sewage flow carried to the digesters. The latter factor alone would permit a concentration of 60,000 p.p.m. of carburizing solution, 30,000 p.p.m. of zinc plating solution and 10,000 p.p.m. of copper plating solution in the sewage reaching the sewage treatment plant before the digestion process would be materially affected.

Acknowledgment

The work herein reported was financed by the Electro-Chemicals Department of E. I. duPont de Nemours & Company, Niagara Falls, New York. Samples of the waste solutions and their analyses were also furnished through the cooperation of this same organization.

Reference

1. Ridenour, G. M., and Greenbank, John, "Preliminary Report on Effect of Cyanide Case Hardening, Copper and Zinc Plating Wastes on Activated Sludge Sewage Treatment." *This Journal*, 16, 4, 774 (July, 1944).

THE OPERATOR'S CORNER

PRESENTING A SHORT COURSE FOR OPERATORS

"Too bad that a larger audience cannot attend these lectures," was our mental observation several weeks ago, as we looked over the program of the Pennsylvania Short Course, recently given at St. Joseph's College in Philadelphia. Hence the idea, somewhat unorthodox to be sure, that the entire series of lectures comprising the short course might be made available to other operators through the medium of "The Operator's Corner." Through the courtesy of the Pennsylvania Sewage Works Association, arrangements have been made to present fifteen of the lectures, in their programmed order, in this and subsequent issues of the *Journal*.

The lecturers presenting the course constitute an impressive "All-Star" cast of sewage works technicians and experts. Their papers contain general coverage of the fundamental functions of various sewage treatment processes, with recommendations as to routine operation practices and suggestions as to the prevention and remedy of common difficulties. New and inexperienced operators will find the series to be particularly instructive.

It is not practicable, of course, to publish all of the papers in a single issue of the *Journal*. Five of them are contained in this issue and the remainder will be carried in the next three or four consecutive issues. All of the regular features of "The Corner" will be continued while the series is being presented.

HELP! HELP!

A surprising number of inquiries have been received at Federation headquarters for information applicable to the development and revision of municipal ordinances providing for the regulation of usage of sewers. Published literature on the subject is limited and complete "model" ordinances are proving difficult to find. Consequently, it has not been possible to render as much assistance as we should in response to these inquiries.

Copies of existing sewer ordinances that are resulting in adequate control of public sewer usage would be of real value. Ordinances providing for control and regulation of industrial waste discharges are particularly needed. If your city has such an ordinance, receipt of a copy will enable us to give more aid to those who seek advice.

W. H. W.

THE REASONS FOR SEWAGE TREATMENT AND THE RESPONSIBILITIES OF THE OPERATOR*

By H. E. Moses

Chief Engineer, Pennsylvania Department of Health, Harrisburg, Pa.

In consideration of any problem it is of advantage to ascertain the various features pertaining thereto, and to that end it may be profitable to consider briefly the reasons for sewage treatment, particularly as these apply to Pennsylvania.

Sewage is a product of community life. It is the water supply of a community made dirty and dangerous in its use by the public. Wherever people are they must have water and, correspondingly, they produce sewage in one form or another. At the isolated individual home this waste is usually disposed of on the premises without too much difficulty. When people live together in communities, however, individual water supplies soon prove inadequate and public supplies are developed, with the natural result that sewerage is also provided. At once there arises the question as to the proper disposal of the sewage. The natural method is to discharge it into a nearby stream and, while the sewage is immediately removed from the vicinity of the community, the stream is contaminated and a hazard is perhaps placed upon a downstream water works. Thus, while a given community successfully gets rid of its sewage, its responsibility extends to its downstream neighbors who rely upon the receiving stream for their drinking water. An important problem is thus created which becomes more and more pressing as the population increases.

In Pennsylvania, most of our public water supplies are secured from surface streams. It is true that a number of communities resort to underground supplies for their needs, but in general throughout the entire State, the rivers and their principal tributaries are relied upon as sources of the major public water supplies. It is immediately obvious that the question of stream contamination becomes of the utmost importance, and there is no more dangerous pollution than that arising from the discharge of sewage without treatment. Sewage is inherently an obnoxious mixture but its real importance arises from the fact that it may produce disease; hence, the imperative need for care in its disposal.

The first public water works in Pennsylvania was installed in 1736, forty years before the signing of the Declaration of Independence. This was at Sheafferstown, Lebanon County, formerly known as the Village of Heidelberg. The supply comprised a hillside spring from which the water was conveyed, no doubt through wooden pipes, to water troughs on the village streets; although Sheafferstown now has a regular public supply, the old system is still operating. From this beginning there has grown a vast system of public water works spreading throughout

* Presented at Lecture-Laboratory Course on Sewage Treatment and Disposal, given by the Pennsylvania Sewage Works Association at St. Joseph's College, Philadelphia, Pa., April 11, 1945.

the Commonwealth, almost 1,000 in number. These supply water to approximately 8,000,000, or 80 per cent of Pennsylvania's total population.

There seems to be no record of the first sewerage system in Pennsylvania, although it probably was installed in Philadelphia. We can, however, refer with some certainty to the conditions obtaining in 1905 when the Pennsylvania Department of Health was organized. At that time most of our principal municipalities had sewerage of some sort, but it is believed that in the matter of adequate sewerage, most of the towns and cities of the Commonwealth were deficient. In many instances, the sewers had been built in a more or less haphazard way without reference to a comprehensive plan.

Today, generally speaking, our larger communities are fairly well provided with sewers. This includes those having populations of 2,500 or more and is almost entirely true of towns of populations in excess of 5,000. At the same time many of the smaller incorporated municipalities are without adequate sewerage.

Substantial progress in the installation of new systems and extension of existing systems has been made within the past decade, especially where municipalities were able to secure aid from Federal agencies established for unemployment relief purposes. Earlier in its life, the Department of Health established a principle requiring the preparation of comprehensive plans for the sewerage of communities which, when approved, can be followed in the building of sewers thereafter. This is a logical method, as well as in the interest of wise expenditure of municipal funds. Accordingly, most of our larger municipalities are in possession of approved comprehensive plans for their sewerage in which some consideration has been given to the matter of sewage treatment.

The treatment of municipal sewage in Pennsylvania is not very old. In 1905 there were about 15 sewage treatment works, only 3 of which were in large communities. The largest was at Reading, installed in 1897; another was at Altoona. The growth of sewage treatment was not rapid for the next few years, but thereafter it proceeded with greater acceleration, so that today in Pennsylvania we have about 300 sewage treatment works ranging in size from the small institution plant to the great North East Sewage Treatment Works in Philadelphia, built in 1923, and having a rated capacity of 60 m.g.d.

From the standpoint of sanitation, the growth of sewerage is a fine thing, providing better living conditions for our citizens and adding greatly to their comfort and welfare. At the same time the pollution load on the streams of the State has been greatly increased and inasmuch as the increase in sewerage systems has not been paralleled by the installation of treatment works, it naturally follows that the contamination of Pennsylvania's streams is much greater than in 1905. It is obvious, therefore, that the need for adequate treatment of municipal sewage has become pressing and the public is insistent that this condition be improved.

Added to the sewage load is that imposed by wastes from industry. Pennsylvania is highly industralized and trade wastes are varied and contribute a heavy burden upon all polluted streams. For example, there are the wastes from coal mines, collieries, washeries, textile mills, canneries, steel mills, milk plants, pulp and paper industries, tanneries, distilleries, and others. It is true that many industries are treating their trade wastes, but much remains to be done in that field.

In the early days of the Department of Health in matters relating to stream pollution, principal consideration was given to the effect of the discharge of untreated sewage on the waters of a stream from the standpoint of its use as a source of public water supply. That conception has been considerably broadened and today the effect of the discharge of polluting matter to streams is measured not only to the extent of its hazard to the public health, but also in relation to its effect on animal or aquatic life, and the use of such waters for recreational purposes. This marks not only a change in the public thinking along these lines, but it has been given a legal status in the so-called Anti-Stream Pollution Law, approved June 22, 1937, under which Act the Sanitary Water Board carries on its program of stream pollution control. Notable in that same Act is the fact that the discharge of industrial wastes, as well as sewage, is also prohibited, except as prescribed by the Sanitary Water Board.

The General Assembly now in session is considering additional legislation concerning the control of stream pollution and bills have been introduced which, if approved, will strengthen the authority of the Sanitary Water Board in dealing with these problems. One item which has occasioned considerable controversy concerns the discharge of coal mine silt into State waters. This has been and is a vexatious problem and the Sanitary Water Board is definitely of the opinion that practical measures can be taken to prevent the discharge of such material into our streams.

The courts have upheld the right of the people to clean streams and a recent decision of the Court of Common Pleas of Philadelphia County contained this statement:

> "And nothing is more fundamental than the right of the people to have the public streams from which they draw their water supply, free from pollution. That right is supreme, for the simple reason that health and life itself depend on it. The people have the absolute right to have the 'ancient purity' of their streams preserved against all other considerations."

There is now an insistent demand that the condition of the State's streams must be improved. To accomplish this end, the Sanitary Water Board has embarked upon a comprehensive state-wide program of stream pollution control. Last summer through a series of hearings held in various parts of the Commonwealth, the Board announced its policy, that sewage and industrial wastes must be treated to a prescribed degree and, pursuant to this policy, has issued orders to nearly 200 municipalities, requiring them to prepare plans for sewage treat-

ment works, and it is expected that additional orders will be sent to about the same number of municipalities, and also to industries, imposing this same obligation. It was realized that due to war conditions, construction of such plants cannot be undertaken immediately, but it is anticipated that such plants will be installed when materials and labor become available after the close of the war. Thus, a new era in stream pollution control has dawned and great progress may be expected in the future. This brings us to a consideration of the part to be taken in this program by the sewage treatment works operator.

First of all, he must have a thorough understanding of the things to be attained. He must have intimate knowledge of the functions and capabilities of each part of his plant. The plant at all times must be adequately maintained. To accomplish these ends, the plant personnel must be instructed as to the several duties. Each operator should explain to his subordinates their part in the organization, the reason for what they do, and the results which should be expected. If a subordinate knows why he is doing a certain thing he will be more interested and quicker to recognize anything falling short of the desired result.

An essential phase of plant operation is the keeping of records, by which is not meant records which are so burdensome as to take up an unproportionate part of the operator's time, but records that are essential to the actual operation of the plant. By so doing, there is built up a history of plant performance which is not only of interest but should be useful for financial purposes, such as budget making, and might, upon occasion, be invaluable in matters of litigation. Perhaps the greatest usefulness of records is for the guidance of the operator.

No plant can be operated intelligently without laboratory facilities. These need not be elaborate, but should be adequate to cover the needs of the particular installation. Plants today are operated scientifically, and unless the operator has facilities for making the necessary tests and understands these tests when made, he will not be able to get the best results out of his plant. The plants of today are based fundamentally on the principles of hydraulics, biology, bacteriology and chemistry. These are the subjects in which the operator requires instruction.

Aside from the features which have to do with the actual operation of the plant, there are others of importance as falling more within the aesthetic realm than in that of actual operation. These features have to do with appearance and include such factors as cleanliness, neatness, orderliness, and condition of plant and grounds. Just as a generally slovenly appearance of either a person or a plant will make a poor impression, contra-wise, if a plant is clean, orderly, and presents a neat appearance, by those things confidence is built up in the mind of the observer, which state is of great importance to the operator. In water works this gives assurance of a good product, and at sewage treatment plants it helps remove the odium—often deserved—which unconsciously is attached to such places.

This principle is well recognized in the design of new plants which are made attractive looking and placed in a setting appealing to the

artistic eye. The operator who has such a plant is fortunate but, even so, much can be done with old plants. Paint helps greatly, while the judicious use of shrubbery on a neatly trimmed lawn will have a beneficial effect upon the observer out of all proportion to the cost of such improvement.

Much can be done by the operator in the education of the public. Suitable publicity in local newspapers and talks before service clubs and other similar bodies will bring home to the public facts which are perhaps little known about the service which is being rendered. The average citizen just takes these things for granted and little realizes the difficulties of operation encountered at the sewage treatment works. Some plant operators, with profit, have encouraged visits to their plants, not only by adults but particularly by school children, at which time a careful and simple explanation is given as to what is being done and how.

Of vital importance is the attitude of the operator toward the public, and he can do much either to make or mar this relationship. The public comes in contact with employees of the sewage treatment works, and the resulting reaction is largely based upon the demeanor and behavior of these employees.

CHARACTERISTICS OF SEWAGE*

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It is always well on commencing a discussion of a particular topic to define it. Sewage is essentially the used water supply of a community to which, in the case of combined systems, may be added drainage waters and associated materials. It may also contain wastes discharged by industrial operations. A term sometimes applied to the waters carried by combined systems is combined sewage, distinct from domestic sewage. As domestic sewage, or the used water supply, is of major interest to this group it may be well to confine this discussion to that type alone. The limitations of time also prevent coverage to a worthwhile degree of the many ramifications relative to combined flows.

Sewage Flows

The volume of sewage flow is predicated primarily on the quantity of water used by a sewered community. In this country an average of about 70 gallons per capita per day is used. Individual conditions vary widely; consumption ranges from 40 to 120 or more gallons per capita per day. The economic status of a municipality appears to coincide quite well with the quantity used. Communities whose major popula-

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tion consists of foreign born, laboring people generally use much less water than middle class or wealthy settlements.

About 50 per cent of the water used by an individual is employed for toilet-flushing. This fact caused a noted sanitary engineer to remark that if it were not for the flush toilet the sanitary engineers would be out of a job. The remaining fifty per cent is distributed among the other common uses, such as washing, kitchen use, cleaning, drinking, lawn-sprinkling and so forth. Normally, from 85 to 90 per cent of the public water supply finds its way to the sewers. This volume is often increased considerably during wet weather by infiltration of ground water into sewers where joints are not tight.

Since the flow of sewage is predicated upon the water supply, it will vary throughout the day depending upon the habits of the inhabitants of the sewered area. Peaks in flow generally occur at rising time, before and after meal hours and late in the evening when a large percentage of people are retiring. Night flows are, in general, only a small fraction of the daytime average. In the case of institutions and cantonments, the peak flows are generally highly accentuated due to the regimented living conditions in such establishments.

The time required for sewage to flow through the sewer system and the presence of collecting wells also has a distinct effect on the variations in flow recorded at a treatment plant. Collecting wells capable of retaining the flow for periodic pumping often tend to reduce the peaks if pump capacities are properly adjusted to specific conditions.

Appreciable variations in the concentration of solids as well as volume of flow in the sewage occur throughout the day. Daytime sewage is usually five to ten times as strong as the night flow. Morning sewage produced at rising time is generally the strongest insofar as solids and B.O.D. are concerned.

Constituents of Sewage

The average municipal domestic sewage consists of over 99 per cent water in which is carried in dissolved, dispersed and floating status a wide variety of substances. Salts, gases, silt and putrescible matter are the common forms these solids take. The salts consist of those originally present in the water supply, plus those discharged by the human body and others emanating from cooking and other kitchen functions. The gases are of similar origin with the addition of those formed by decomposition of putrescible matter in the sewers. Silts consisting of sand, gravel and clay find their way into sewage through the washing of vegetables and other objects and from soil washing into manholes and leaky sewer joints. Of major interest is the putrescible material or organic matter present, as it is these substances which exert the greatest oxygen consuming effect on the stream and, consequently, they are of greatest concern in sewage treatment. Matter having this general classification is present in sewage in suspended, dispersed and dissolved forms. Illustrative of such matter are soaps, fats cellulose, proteins

and derivatives thereof. These are the materials which serve as food for the omnipresent bacteria whose life processes account for the instability of sewage.

Fresh sewage is normally not objectionable as to odor, generally having only a soapy or laundry-like odor. On relatively short detention, particularly at high temperatures, the bacteria present set to work on the organic matter producing a number of substances exhibiting foul odors, corrosive characteristics and the ability to affect treatment processes detrimentally. Hence it is desirable to obtain sewage in a fresh state for treatment wherever possible.

Another characteristic of sewage which is of interest is its temperature. In this climate the collected sewage seldom falls below 50° F. This is due to the quantities of hot water normally in use and is of importance in that freezing at exposed treatment units is prevented.

In addition to the materials mentioned above, considerable material which may be classed as debris finds its way into the sewage flow and is carried along by it. Sticks, stones, leaves, rags and dead animals are illustrative of these materials. Such materials are of interest in that they are often involved in sewer stoppages and must be screened out prior to treatment to protect the operating equipment.

It might be well at this point to set down a classification of the solids present in sewage and to comment briefly on their individual significance as far as sewage treatment is concerned. The following outline representing the composition of average domestic sewage will serve this purpose:

1. Screenings { Coarse / Fine
2. Grit
3. Total solids (500 p.p.m.) { Volatile (260 p.p.m.) / Ash (240 p.p.m.)
   - *A.* Total suspended solids (200 p.p.m.) { Volatile (160 p.p.m.) / Ash (40 p.p.m.)
     - (1) Settleable (120 p.p.m.) { Volatile (90 p.p.m.) / Ash (30 p.p.m.)
     - (2) Non-settleable (80 p.p.m.) { Volatile (70 p.p.m.) / Ash (10 p.p.m.)
   - *B.* Dissolved solids (300 p.p.m.) { Volatile (100 p.p.m.) / Ash (200 p.p.m.)

In terms of oxygen demand the dissolved solids, the non-settleable suspended solids and the settleable suspended solids each account roughly for a third of the total. Thus, primary settling which removes the settleable suspended solids can be expected to reduce the total oxygen demand about 35 per cent. Chemical coagulation will remove in addition the non-settleable solids, raising the over-all removal to about 65 per cent. Oxidation processes such as the trickling filter and acti-

vated sludge are capable of decomposing the dissolved organic matter, hence are able to reduce the oxygen demand of sewage in excess of 85 per cent.

SEWAGE TREATMENT PROCESSES AND RESULTS *

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By definition there are only three processes of sewage treatment: primary treatment, secondary treatment, and disinfection. A fourth important part of any sewage treatment operation is the by-product process, solids disposal. Sewage treatment, as the name implies, is the treatment of liquid wastes to remove or eliminate matter which causes nuisance, and to eliminate or destroy disease producing organisms. All methods of treatment fall into these three basic processes and their by-product process of solids disposal. Discharge of untreated sewage into large bodies of water is sewage disposal by dilution.

Sewage Treatment Processes

Fundamentally, sewage treatment is for the purpose of protecting public health and preventing any and all nuisance conditions in a receiving body of water. All receiving bodies of water have a certain inherent capacity for carrying on sewage treatment processes within themselves, and disposal by dilution depends entirely on that capacity. When such capacity is overtaxed, the construction of sewage treatment plants is necessitated.

The choice of the processes and methods of carrying them out is dependent on the extent to which this natural capacity is to be utilized. Any decision on the matter must include consideration of the uses to which that receiving body of water is put, *i.e.*, water supply, fish culture, recreation, commercial transport route, etc. From these considerations come not only the choice of the basic treatment processes to be used, *i.e.*, primary, secondary or disinfection, but also the methods by which they will be carried out.

Primary treatment is the removal of solid particles by physical and mechanical means. Screening, grit removal, grease removal, and sedimentation are included in this process. Important adjuncts or aids to primary treatment, or methods of improving the efficiency or effectiveness of the process, include chemical precipitation, flocculation, removal of finely divided solids by aeration and vacuum flotation and the removal of grease by air, or air and chlorine combined. The slow sand filter is a primary treatment process in that it is a mechanical means of straining out solid particles. It is also a secondary process in that

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it depends on biological activity for destroying these solids so removed. Sand disk screens are also a method of primary treatment, as are storm water settling tanks.

Secondary treatment is an oxidation process—a process of removal of finely divided solids and colloidal matter and the stabilization and oxidation (wet-burning) of these solids and the dissolved organic matter by means of air and the activity of living organisms. The trickling filter and the activated sludge process are the fundamental and best known methods for accomplishing secondary treatment. Important adjuncts, aids or improvements which increase the efficiency of the trickling filter are preaeration, and recirculation of the filter effluent with higher rates of application of the liquid to the filter. Aids or modifications in the activated sludge process are the addition of chemicals (the Guggenheim process), tapered aeration, the Hayes process and the Mallory process.

Disinfection signifies the destruction of pathogenic or disease carrying bacteria; it does not mean the complete killing (sterilization) of all bacteria and lower forms of life in the sewage. Disinfection is generally accomplished by the introduction of chlorine as a solution, or the introduction of a hypochlorite solution. Most modifications of the disinfection process relate to the point of application of the disinfectant, and its possible use to control odors. Where chlorine or chlorinated products are used only to control odors, disinfection, *per se*, is not involved.

Solids disposal, as the name implies, includes all types of solids removed in the treatment of sewage. Screenings may be buried, burned, or ground and returned to the sewage as organic solids to be removed later as sludge. Grit may be buried or, if relatively free from organic matter, it may be used as fill or as a filter media in sludge drying beds. When high in organic matter it may be burned. Grease may be buried, burned, or possibly under some conditions, recovered.

Suspended matter removed by sedimentation and handled thereafter as a sludge may be barged to sea; dewatered, dried and burned; digested (with or without gas recovery) and dried on open or covered sand drying beds; chemically and mechanically dewatered, dried and burned; or it may be dried and sold as fertilizer. Elutriation of such sludge is for the purpose of aiding in dewatering before drying and burning. Sludge from secondary treatment processes may be subjected to the same treatment as primary sludge, i.e., digestion, burning or drying for fertilizer purposes. Final disposition of solids which are not sold or used as fertilizer, is as fill, usually near the plant site.

With this brief outline of sewage treatment processes and the methods available in each, it is possible to examine the choice of these methods from a design standpoint, as dictated by the extent to which sewage treatment must be carried out. Often a factor to be considered in the choice of the process or of methods used may be the area available for the plant site. Still another factor besides the extent of treatment desired is the cost of installation versus the cost of operation.

Primary Sewage Treatment Process

In the matter of screenings and grit removal the design will probably depend on the preference of the consulting engineer, or on the bid price for the equipment needed. Whether the screenings are ground sub-aqueously or out of water is not finally determinable by data on the effectiveness of the two methods. Whether screenings will be hand or mechanically raked will depend on the size of plant and funds available for construction.

Grit chambers are usually designed on the basis of the fundamental concept of sedimentation. That is, the design is related to the velocity necessary to keep organic particles in suspension while allowing inert particles to settle. Here the design is dependent on Stokes' law of sedimentation and the relation of specific gravity to velocity. Modifications in design are usually concerned with distribution of flow and control of velocity, and with methods of collecting and removing the settled grit. Washing of the grit will depend on the need for removing putrescible matter before the grit is disposed of. In general, washers of various design accomplish the desired results. Generally, too, such grit washers fail to remove garbage particles which are prevalent in the grit from the larger communities.

In the removal of suspended matter by sedimentation there are several factors which affect the efficiency of the process. These factors include the concentration of the suspended matter (p.p.m.), the detention period (strictly speaking, the flow-through period), the distribution of flow (*i.e.*, extent of short circuiting), the extent of comminution (dispersion) of the solid particles in the sewage and, to a lesser degree, theoretically, the temperature of the liquid.

Whether circular tanks or longitudinal tanks should be used is a debatable question. Likewise the type of sludge collecting mechanism used is not of particular importance in the actual operation of the sedimentation process. Arguments concerning the preference of circular over longitudinal tanks usually revolve around the matter of distribution of flow. All efforts to improve the flow characteristics in either type of tank are intended to prevent short circuiting and to make the actual flow-through time approach the detention time, *i.e.*, the theoretical time that any small portion of the sewage takes to pass through the tanks.

It is well known that changing the baffles in longitudinal and circular tanks will often improve the efficiency of sedimentation and, consequently, the removal of solids. Aside from such considerations the efficacy of various methods of primary sedimentation may be considered. Plain sedimentation for a period of one to two hours may be generally expected to remove from 30 to 50 per cent of the suspended matter present in the raw sewage and at the same time to remove 20 to 30 per cent of the 5-day B.O.D. In highly efficient tanks with detention times of 2 to 3 hours, where the suspended matter reaches the treatment works with very little dispersion or subdivision of particles, the removal of the raw sewage suspended solids may reach 60 to 70 per cent.

Aids to Primary Sedimentation

As an aid to primary sedimentation, flocculation, or the building up of particle size by slowly mixing the sewage before sedimentation, may increase the removal of suspended matter from 40 per cent to 60 per cent. A primary treatment method in development is the treatment of sewage with air followed by the application of a low vacuum which causes the fine air bubbles to rise, carrying up small particles of suspended matter and grease. This method claims a removal of approximately 10 to 15 per cent more suspended matter than plain sedimentation. Grease removal with air, or air and chlorine, depends on the quality and amount of grease present and its characteristics as well as the design of the device and the amounts of air and chlorine added.

Slow sand filters will remove 90 per cent or more of suspended matter from raw sewage. Sand disk filters, in reality Reinsch-Wurl screens covered with sand or crushed coal, remove approximately 20 per cent of the suspended matter at best and less than 10 per cent when no filtering medium is used. Electrodialysis as an aid to flocculation gives results in laboratory experiments of 80 per cent removal of suspended solids and 70 per cent removal of B.O.D.

Chemical precipitation with either aluminum salts or iron salts and lime will aid in the removal of suspended matter and the extent of the removal will depend largely on the amount of chemicals used. By using large quantities of chemicals it is possible to remove 90 per cent of the suspended matter and 80 to 85 per cent of the 5-day B.O.D. Cost of such treatment is generally quite high and may be prohibitive unless the plant site is so small as to demand the installation of a highly effective method utilizing a small area. In general, such quantities of chemicals are not used, and the extent of removal of solids is about 60 per cent with the B.O.D. removal about 50 per cent or better. By means of chemical treatment it is often possible to increase the effectiveness of the primary process, thereby decreasing the load on the secondary process. Thus the need for further additions to plant capacity in the secondary treatment process may be eliminated.

Bases of Comparing Primary Sedimentation Results

Whereas the above comparative results have been given in terms of suspended solids removal, it should be remarked that this method of rating the efficiency of sedimentation processes is misleading and improper, if not antiquated. A much better and more applicable method of rating sedimentation processes is to compare the efficiencies as to removal of settleable solids. Obviously, as indicated above, the amount of suspended matter removed will depend on the concentration of suspended solids and the particle size and density. Some solids should not be expected to settle under any conditions of time and space. Therefore, the obvious comparative basis is the efficiency of removal of settleable solids. This efficiency is ascertainable only from the determination of the settleable solids.

Although this test is now used at a number of plants throughout the country, it has not been included in previous editions of *Standard Methods for Sewage Analysis* and only recently has a standard technique been proposed. Without information from this test available, it is impossible to make comparisons of different methods of primary treatment on this basis, but it is believed that flocculation as an aid to primary sedimentation will increase the removal of settleable suspended solids by 10 to 20 per cent, and effective chemical precipitation will, of course, extend this removal. Aeration and vacuation as recently proposed is apparently as effective as plain flocculation in the removal of suspended matter and also seems to offer additional advantages.

Secondary Treatment Process

In the matter of secondary treatment it is quite generally accepted that trickling filters and activated sludge can be designed to produce approximately the same results. The area required for trickling filters is much larger than for activated sludge but operation costs for the latter are quite an item considering the air required, whereas in the case of trickling filters there is relatively little cost of operation. Possibly the activated sludge method of secondary treatment will give slightly higher removals of B.O.D. but the method is more susceptible to shock than the trickling filter and may offer several other problems in control.

The high rate filters depend on higher application rates of sewage and on recirculation. This system makes use of the fact that the living organisms on the rock can assimilate and oxidize greater amounts of organic matter if the air is sufficient and the concentration of the organic matter not too high. Recirculation of the effluent of the high rate filter, either to the filter itself or to the primary tank influent, not only dilutes the concentration of the applied sewage but also brings the organic matter that has passed through the filter in contact with the organisms again. The capacity of the trickling filter is thus stepped up to four or five times that of the ordinary filter. Conversely it may be stated that the size of filter required is reduced to one-fourth or one-fifth of the ordinary trickling filter. Installations of these types of filters in army camps have proved to be quite effective in the treatment of sewage containing as high as 400 p.p.m B.O.D. Instances are reported wherein the B.O.D. is lowered to the vicinity of 10 p.p.m. The choice of particular method of application of sewage to these filters, the number of filter units in series, and the method of recirculation is one of individual preference and the difference in obtainable results is not within the scope of this general discussion. It must be borne in mind, however, that the high rate or high capacity filter costs more to operate than does the standard rate filter.

Aids to Activated Sludge Treatment

Activated sludge processes may be improved by varying the amount of air introduced at different sections of the aeration tanks. This is

known as tapered aeration and consists of adding about 50 per cent of the total air to the first third of the aeration process, thirty-five per cent of the air to the next third, and the remainder of the air to the last third of the aeration tanks. Increased capacity and increased ability to withstand shock are claimed for this system of aeration. A variation of the tapered air scheme is that of distributed input of settled sewage to the aeration units—notably the New York City practice.

The planned addition of an iron salt to the aeration process constitutes the Guggenheim process. It is generally recognized that where industry contributes moderate quantities of iron-bearing wastes to the sewer system, superior results are realized and a more stable system is observed. This condition, of course, antedated the Guggenheim patents by a number of years.

The Mallory, or "Oxidized Sludge" process for secondary treatment is likewise an aeration and sedimentation process with the control of the relation of aeration time to sedimentation time as the outstanding feature. The process seems to serve well under heavy loadings such as those imposed by milk wastes, from which B.O.D. removals as high as 99 per cent have been claimed.

The Hayes process for secondary treatment involves contact aeration in two stages. It has been successful in small installations in the Southwest but has not proved adequate in several army camp installations where the load has been high. Paddle-wheel and other mechanical aerators are mere variations of the activated sludge process. In general they have not been widely installed in this country.

A valuable aid to the activated sludge process originated at the Lima, Ohio, plant. Here the method of correcting or preventing sludge bulking by mild chlorination of the recirculated (return) sludge was first instituted. The practice has spread and New York City, among others, makes effective use of the Lima method.

Disinfection

The extent to which disinfection is practiced is dependent principally on the use of the receiving body of water as a source of water supply. If the dilution is relatively small, disinfection may have to be carried to a greater extent than if dilution and distance to the next water supply are great. In any event the amount of chlorine required will depend not on the number of original bacteria in the sewage or the number desired in the effluent but on the chlorine demand of the sewage. Not until the chlorine demand (amount of chlorine used up in chemical combination with substances in the sewage) is at least partially satisfied will the bacteria be killed to any extent.

The actual kill depends on the amount of chlorine added, the amount of excess or residual produced, the type of chlorinated compounds formed in the sewage when the chlorine is added and, most important, the time allowed for the chlorine and chlorinated compounds to act on the bacterial protoplasm. All of the bacteria are not killed; some may be revived on dilution or regrowth may occur from those left, but where

the dilution is large and the normal enemies of bacteria in the receiving water sufficient, regrowth is generally not great.

In determining the efficiency of the disinfection treatment it is incorrect and misleading to report results in per cent kill based on the original number of bacteria present. This is obvious from the simple arithmetical relation that 99 per cent kill of 500,000 leaves 5,000 bacteria per unit volume whereas 99 per cent kill of 50,000 leaves only 500 bacteria in the disinfected effluent. For consistent comparisons of disinfection in winter and summer months the results should be reported in the number of unkilled bacteria after disinfection. Where the dilution is large, concentrations of coliform bacteria in the effluent may be as high as 1,000 per ml. without creating an undue load on a water filtration plant downstream.

When dilutions are small disinfection should be carried to a greater extent. In this connection it should be remembered that if organic matter, suspended or dissolved, is not removed from sewage, no amount of disinfection will prevent that matter from decomposing at some later time when the bacterial population has been re-established. Thus the discharge of chlorinated sewage into a small stream affording a low dilution merely moves the point of nuisance farther downstream or otherwise delays the bacterial degradation of the organic matter.

The point of application of the chlorine in sewage treatment may depend on several factors. If the chlorine is added up-sewer it is usually for the purpose of odor prevention, principally by killing the bacteria which will convert sulfates into hydrogen sulfide. Addition of chlorine prior to sedimentation is prechlorination and usually prevents odors as well as provides longer contact time for the chlorine to act as a disinfectant. Prechlorination may, by preventing the formation of hydrogen sulfide in the settling tanks, also reduce the amount of chlorine required for disinfection. For a normal domestic sewage prechlorination probably does not require much more chlorine than does post-chlorination.

The length of time required for disinfection (contact time) should be at least 15 minutes with a residual chlorine at the end of that time of possibly 0.5 p.p.m. If further contact time is available after 15 minutes, the residual at 15 minutes may be as low as 0.1 p.p.m., or there may even be a slight chlorine demand at that time. Chlorinated compounds formed in sewage act as bactericides if given sufficient time of contact. In large plants, where chlorination is important, it may be economically advantageous to utilize these chlorinated compounds rather than depend on high chlorine residuals for short contact times.

General Considerations

It is apparent from the above observations that each method of treatment has its use and application. Combinations of the processes or even of several methods in a single process may prove to be advantageous for a special problem. Usually each installation of a sewage treatment plant is a separate problem.

Disinfection is rarely practiced alone except where it is desired to eliminate a nuisance in the immediate vicinity of an outfall and allow the sewage to become more diluted before bacterial activity sets in. Primary treatment, to remove suspended matter, and chlorination are used when it is desired to reduce local nuisance and protect water supplies. This combination usually occurs where the dilution is great.

Primary and secondary treatment are usually combined when it is necessary to eliminate organic and bacterial nuisance completely and, as a further protection for bacterial removal, post-chlorination may be added. Secondary treatment alone is not practical. The choice of the method of carrying out these primary and secondary treatment processes may best be determined by the designing engineer when he decides on the amount of the load that each process should carry. This decision may well rest on the economics involved.

For example, at one installation a very small part of the load may be carried by a settling tank designed to remove only the coarse materials with the rest of the load to be carried by the activated sludge process. Conversely, preaeration of sewage before discharge onto trickling filters may be more economical for another plant. Choice of high rate filters as against standard rate filters and activated sludge likewise is a matter of economics in many instances.

Solids Disposal

The type or method used in solids disposal is quite generally decided on the basis of the economics involved. Obviously, for a small community, vacuum filtration, drying and incineration are not feasible because of the smallness of the equipment required and the personnel necessary to operate such equipment. Sludge digestion and drying on sand beds remains the best method in such plants.

For such small installations which do not have heated digesters, the sludge may be reduced by about fifty per cent in volume and the solids 25 per cent by weight; with heat the reduction is greater. In larger cities, sludge digestion, mechanical dewatering, drying and incineration appear to offer many advantages, particularly if the available land for ultimate disposal by fill is not conveniently located. Whether the sludge is sold or given away as fertilizer depends primarily on the local market and the fertilizer value of the sludge which, in turn, may depend on the type of treatment of sewage or the extent of digestion of the sewage solids. Barging of sludge to sea is a matter of locality as well as economics.

Inasmuch as the disposal of solids is but a by-product process of sewage treatment and not sewage treatment itself, comment on the methods of such disposal and results obtained are not primarily a part of this presentation.

Summary

In summary, it is sufficient to say that whether choosing the type of treatment process, the method of carrying it out, or the method of dis-

posing of the important and nuisance giving solids removed, the important considerations in the decision as to choice rest on the realization and understanding of the following basic factors: (1) the use of the receiving body of water, (2) the capacity of the receiving body of water to receive sewage, (3) the size of the plant site, (4) the availability of dumping grounds for the by-product, and (5) the economics involved in adjusting the relation between the various processes and/or the methods used between first cost and operation costs. This is but another way of saying that the choice of sewage treatment processes or methods should depend on the extent of treatment needed or desired and the best results obtainable from various combinations of these methods at the lowest possible cost for installation and for operation.

THE CARE AND OPERATION OF IMHOFF TANKS *

By P. N. Daniels

Superintendent of Sewerage, Trenton, N. J.

The Imhoff tank had the misfortune to be born long before the principles of sludge digestion were known and, as a result, probably the majority of them were under-designed as to sludge capacity. Shortly after such a tank was started, it resembled a gigantic chocolate ice cream soda, much to the detriment of the effluent and grief of the operator. As a consequence, the design received a great deal of bad publicity, even though for small installations it was and is a fairly efficient and foolproof type of sedimentation, provided that there was sufficient sludge storage plus intelligent handling for a year or so at the start.

The three principal parts of an Imhoff tank, *i.e.*, gas vent or vents, flowing through compartment or compartments, and sludge storage chamber or chambers, perform the same functions whether the tank proper is round, square, or oblong in plan, and operative control will not vary except in minor details. As it is not the purpose of this paper to go into matters of design, the following factors are given without comment to indicate capacities and relationships which should prevail:

(1) Detention period—2.5 hours at average flow.
(2) Ratio of length to width of settling compartment—not less than 3 to 1 or more than 5 to 1.
(3) Slope of bottoms of settling compartments—not less than 1.0 horizontal to 1.25 vertical.
(4) Slope of sludge hoppers—not less than 1.5 horizontal to 1.0 vertical.
(5) Sludge storage—3.0 or more cubic feet per capita.

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Settling or Flowing-through Compartments

As the settling compartment is the place where the actual work of separating solids from the sewage is accomplished, it is very necessary that every effort be made to see that the walls, slopes, weirs, channels, and baffles are kept clean at all times. In theory, the sewage solids are supposed to slide down the slopes and through the slot automatically and without urging, mechanical or otherwise. Actually, no matter how smooth the surfaces, the film of grease and soap curds which accumulates will act as a fly paper to entrap flocculent matter, which if allowed to remain, will putrefy and break off in masses from time to time. This usually adds a lot of solids to the effluent and may accelerate odor production.

There are a number of methods and tools in use for cleaning the channels, among them being rubber faced squeegees on long handles of the type used by professional window cleaners; scrapers of wood or metal; chains on one or two poles, to be dragged along the slopes above the slot; hose streams; brushes and long handled hoes or shovels.

The frequency of cleaning depends a great deal upon the time of the year, characteristics of the sewage, and the initial smoothness of the areas in contact with the settling sewage. In hot weather the slime deposit will become septic almost overnight which means that daily cleaning is necessary in the summer, whereas twice a week may be enough in the winter. A sewage containing large amounts of grease will foul a tank rapidly and require more housecleaning activity. Rough concrete acts as a perfect foundation for the accumulation of solids, and cleaning is indicated more often than if very smooth surfaces were provided initially.

All cleaning operations should be done slowly so that the dislodged solids will not be broken up and widely dispersed to be carried over the effluent weirs. Operations should, of course, be from the top of the slopes down to the slots, with a final chaining of the slots for the final cleanup.

Cleanliness should extend to the various auxiliary parts of the tank system such as flow reversal channels and pipes. These passages are usually very flat as to grade and may rapidly accumulate scum and solids in and out of service unless they can be emptied completely. Cleaning is especially important prior to reversing the tank flow.

The handling of scum presents a major problem in some instances; particularly when the tank is not preceded by screening and grit removal. Here again, cleanliness is essential to the proper functioning of the unit. Thorough baffling at inlets and outlets should be installed if not already in place, thus forming easily accessible locations for the accumulations to lodge. Scum may be removed by skimming with wire screen baskets, disposing of it into the gas vents if the quantity is not too great. This is also contingent on the amount of floating fecal matter and other readily decomposable solids which might cause odors. Before the skimming, some of the floating material can usually be sent

to the bottom by hose spraying, stirring with a long handled shovel or paddle or by towing a floating board upstream in the settling compartment. This disturbance of the scum releases gas from small buoyed up particles which normally are heavier than water, allowing them to get down to the slot and sludge compartment. At Trenton we have a clear settling compartment on either side of the gas vent so we use a board with two chains attached to the leading edge, *i.e.*, the edge on the towing side. The two workmen pulling the board by these chains slap it up and down by jerking on the lines, which does a good job in sinking settleable solids. This procedure, of course, is not possible unless there is a free area not obstructed by walkways, etc.

Gas Vents

The proper handling of gas vents has long been a debatable question as far as the scum formations are concerned. Some operators advocate keeping the scum broken up daily, so that the surface of the vent is more or less liquid at all times, while others let scum accumulate as it will. The writer believes that the scum should be undisturbed as long as it stays above the slot level and does not cause belching through the slot from trapped gases. The materials collecting in the vents are of such character that they digest slowly, and it would seem more reasonable to let them stay in the large storage volume in the gas vent above the slots, which otherwise is unused. This adds considerable capacity to the over-all sludge digestion chamber and does not, as a rule, affect sedimentation. Of course, if the digestion and settling rate is less than the rate of accumulation, the solids will back up through the slots, and a prompt application of a hose is indicated plus a long handled plunger affair to break up the scum and get most of it down below the slot. Here again the operator must work slowly, as water added to the gas vents must come up through the slot; large amounts will carry solids up from the sludge chamber.

It is not believed that odor nuisances result from the practice of leaving the gas vent scum undisturbed unless there is some other cause present. Fly breeding is not possible under normal conditions due to the wetness of the scum a few inches under the surface.

Sludge Digestion and Storage Chamber

Sludge management is the one big problem in Imhoff tank operation; if there is insufficient sludge capacity, the operator is helpless unless he can find some way to increase the storage capacity with lagoons or other means. This is particularly true when only one tank unit is available; with several tanks some manipulation is possible.

The action which takes place during sludge digestion is a "mineralization" of the highly putrescible organic matter of the sludge to a more or less stable form, changing it from a foul, gray, slimy substance to a black mud with a tarry odor which will drain and dry readily on a sludge bed. In general, sludge is made up of water; inorganic material

(about 75 per cent); organic compounds such as sugar, starches, cellulose, etc., composing the carbonaceous group, and urea, proteins, amino acids, etc., in the nitrogenous group; fats; and bacteria and protozoa.

The carbohydrates and fats digest more readily and start the decomposition process by breaking down into organic acids which reduce the pH from around 7.0 to 6.0 or less. Hydrogen sulfide, nitrogen and carbon dioxide are the gases formed. It is in this stage that the sludge begins to do tricks, either all rising into the gas vent space or stratifying, usually leaving a few feet of liquid at the bottom. This is especially disconcerting to the operator planning to draw off some sludge —to find that there is none within reach of the withdrawal pipe. This condition will rectify itself with the establishment of a digestion balance, as well digested sludge will not float unless impregnated with gas, a condition not found in the bottom of a tank. Following this stage the nitrogenous materials break down slowly and the organic acids present decompose to ammonia nitrogen. The pH starts to rise toward neutrality. As a final step the most resistant materials are attacked, a larger proportion of methane is found in the gases, the sludge turns black, and the pH is above 7.0.

The time all this takes is mainly dependent on the temperature and seeding of the sludge. Unseeded sludge, at a low temperature, say below 50° F., will remain completely inactive for a long time, perhaps years. Seeded sludge at pH 7.2 and 85° F. will digest completely in 30 days.

It is impossible, of course, to keep an Imhoff tank at 85° F., the usual temperature range being about 55° F. to 75° F. and probably averaging 60° F. the year around. Most tanks are at or near ground water level, so that the heating effect of the warm sewage is partly offset by the fairly constant low temperature of the ground water. As the operator cannot control the digestion temperature, he must then look to manipulation of sludge additions and withdrawals to effect his purpose, which is to set up a predominantly alkaline sludge compartment.

Starting with a new tank, it is advisable to seed the sludge chamber with well digested sludge from another plant. The quantity to be used is highly indeterminate—authorities differ widely, their recommendations ranging from 2 per cent of the sludge compartment volume to 4 parts of seed sludge to 1 part of new. About the only sound advice that can be given is the more seed sludge the better. Substitutes for digested sludge are rotted leaves, decomposed manure, cesspool cleanings, or other stabilized organic matter.

The sludge chamber of a new tank, usually filled with fresh water prior to starting the flow of sewage, should be brought to pH 7.0 to 7.2 and held there by the use of lime in solution fed by any method which will keep the lime from depositing with the sludge before dissolving. Small quantities fed frequently are better than large amounts at longer intervals. As to quantities to be fed, this can be determined in the laboratory, using a known strength of lime solution to treat a definite quan-

tity of sludge. The sample should be a mixture comprising portions taken at various points in the tank. Liming should not be resorted to unless the pH is quite low; it should not be continued after a normal pH balance is achieved.

If a tank has sufficient sludge capacity and has been properly broken in, no trouble from foaming should follow. There is, of course, the precaution to be observed of not drawing off too much sludge at one time—small quantities frequently should be the rule. It is also advisable to remember that the digestion process is nearly dormant during the winter, so that just before cold weather sets in, a maximum storage capacity should be available to carry over the winter season.

If foaming does occur it may be cured by several methods, most of which may have to be tried before the desired result is obtained. In a multi-tank installation the offending unit may be cut out of service and given a rest to allow alkaline digestion to supercede the acid stage. Recirculation of the sludge may accelerate the formation of ripe solids and the restoration of digestion balance. Pumping the partially digested sludge below the slot to a lagoon or sludge bed will relieve the load and expedite a return to normal.

While attempts at curing the condition are being carried out, there is still the problem of keeping the foam in the gas vents and out of the settling compartments. Water sprays give the best results with a minimum of labor, either using fresh water from the mains or supernatant liquor pumped from the slot. The latter is considered the best practice as it involves no interchange of liquids through the slot as is the case when fresh water or effluent is added to the gas vents.

Mechanical agitation with paddles, brooms or other means will control a mild case of foaming temporarily, but with severe conditions it would be a waste of time.

Samples and Sampling

The writer has never been in favor of sampling and analyses for the sake of compiling a lot of statistics which are possibly of academic interest but are of no practical value in operation. The trained eye of the experienced operator is often worth more than many laboratory determinations, and this is true no matter what process is involved.

During the breaking-in period, suspended solids, settleable solids, pH of sludge (top and bottom), volatile solids in sludge, total alkalinity of sludge compartment contents (cross section), and per cent moisture in sludge are all useful in charting the changes occurring in reaching a stable condition. Of these the total alkalinity is perhaps the most important as it is more reliable in indicating the trend than is pH. A drop in total alkalinity shows that a digestion balance is not being maintained, while rising values indicate an approach to equilibrium. The range in a tank in good condition should be from 2,500 to 4,000 p.p.m. with extreme limits of 1,300 to 6,200 p.p.m. Acid or alkaline foaming may be expected above and below these limits.

As a measure of sedimentation efficiency, suspended solids and settleable solids may be run daily for a while to establish a norm for the plant, after which the settleable solids (Imhoff cone) test is reliable enough to indicate routine efficacy. Suspended solids data yield accurate removal values and trends of sewage characteristics but daily determinations are usually not justified.

There are various devices employed to sample at known depths in the tank such as bottles fastened to a long pole, with strings leading from the stoppers to the top end of the stick; a pitcher pump with weighted suction hose; or one of the patented sludge samplers. The writer prefers the pitcher pump arrangement, as by lowering the hose slowly while the pump is being operated a very definite "kink" or "jerk" may be felt when the end of the hose enters the sludge zone from the supernatant liquor. This is a very helpful determination when one is trying to keep the sludge level in a narrow range below the slot. It has the added merit of being rapid.

Alterations by the Operator

Quite often a little study on the part of the operator will reveal inexpensive plant alterations which will materially improve results. For instance, the baffles in the tank may often be supplemented, moved away from or toward inlets and outlets, raised or lowered, or otherwise adjusted with beneficial effect. A case in point is the Trenton, N. J., plant where four tanks in a battery are fed from a single crosswise channel discharging over eight long weirs, two to a tank. Theoretically, the sewage is expected to change its course 90° at each weir—actually it slides over the weirs at an acute angle and strikes the side walls before straightening out for the length of the tanks. This short circuits practically half the volume, as indicated by dye tests. To remedy the condition, the weirs were replaced by planks with orifices and, in addition, a boiler plate deflector was hung on the upstream side of each orifice, so that the entering sewage was immediately turned at right angles to the channel flow. Settling efficiency was promptly increased by 10 per cent.

Very often a plant is so located that sludge drying and disposal can be simplified by building a lagoon at small cost. Time after time the writer has seen plants at which the operator carefully dries the sludge, then laboriously wheels it to a nearby hollow as fill. A few dollars for pipe will often permit liquid sludge to be handled through to dryness on the dump by merely turning a valve. At Hamilton Township, N. J., the plant was located at the edge of a 400-acre swamp. By building a dike with ashes and other non-combustible fill, a lagoon was formed large enough to receive all sludge produced for the next 20 years, effecting a saving to the municipality of about $5,500 per year in operating costs. Another advantage of a lagoon is for storage of incompletely digested sludge in case of trouble at the Imhoff tanks. Removal of top sludge by pumping is almost always a certain and rapid cure for foaming.

OPERATION OF INTERMITTENT SAND FILTERS*

By Francis E. Daniels

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This paper is primarily a review of operation practices at intermittent sand filters used in sewage treatment but, since it does not appear to be covered elsewhere in this program, it may be well to discuss some of the more primitive methods of treatment of water-borne excreta which preceded and led to the development of the intermittent sand filter.

Disposal on Land

The disposal of sewage on land, sometimes known as broad irrigation or sewage farming, is, perhaps, the oldest method of sewage treatment. It is probable that human excreta has been utilized on land in China and Japan for thousands of years, while as early as 1559 a sewage irrigation area was established in Prussia. Later on considerable attention was given to sewage farming in England, and afterwards irrigation areas were established in many places on the Continent. In 1876 the first area for the city of Berlin was put in operation, to which other areas have been added, until thirty years ago the farms were estimated to be the largest in the world, covering 50,000 acres of ground.

One objection to sewage farming is the large amount of land required, as usually only about 10,000 gallons per acre per day can be successfully treated upon a broad irrigation area, while ten times that amount can be handled on good sand beds. Unless carefully managed, the process is likely to be objectionable, if near built-up communities, on account of odors, flies and unsightliness. However, 4,000 people have actually resided on and cared for the sewage farms of Berlin, and considerable quantities of forage, cereals, and vegetables have been raised. Even fish were raised in some of the ponds and drains, and were made to yield a revenue. In some other localities good crops have been produced, notably in California; but all in all, sewage farming is not a paying operation, and has lost favor except, perhaps, in very dry regions.

A low or marshy area should never be selected to receive sewage because there is danger of a nuisance without purification of the sewage. Light, sandy or loamy soils with free drainage are the most suitable, while stiff clay is almost worthless.

The areas should be laid out with some system, so as to dispose of the water to the best advantage. If crops are grown, good judgment must be used in the selection of the kinds which will be the most suitable under each particular local condition. The attendant must know just how much water each crop can stand, and to preserve the proper balance between the raising of crops and the disposal of the water often requires considerable skill and experience. Usually in wet weather,

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when the crops need the least added water, the sewage flow is the greatest; hence its disposal at such seasons is more difficult.

Grease and the larger suspended solids should be excluded, as these often seriously interfere with the growth of certain crops. The furrows or ditches should be laid out so that the sewage is distributed evenly over the area, and in such directions that the ground is not washed in gullies in times of showers. The flow should be changed frequently from one area to another to prevent any part of the field from getting "sewage sick."

Corn and forage crops are raised and sometimes fruits and vegetables, but there is quite a sentiment against the growing of crops for human consumption upon sewage farms. Certainly berries, salad greens, celery, low growing fruits and vegetables which are eaten raw, should not be cultivated. Where land has been available, there have been instances where the water has been diverted from fields for a season and then heavy crops were raised upon the rested areas.

Although somewhat apart from the subject, it may be well to mention that extended sewage areas often have a direct effect upon neighboring wells. Such wells should be examined frequently, and in new works the wells in the vicinity should be considered. English researches "have shown that specific bacteria may pass for a distance of two miles in less than three days through chalky soil of a porous nature."

For small estates and institutions a system of ramifying lines of underground, open-jointed tile pipes provides a very suitable method of disposal for the liquid wastes. As much grease and suspended solids as possible are retained in cesspools or tanks and the overflow liquids are intermittently discharged into the pipes and allowed to soak away. The area is laid out in units so that the flow may be diverted from one unit to the next in rotation. A dry, free draining location, with porous soil, should be selected and great care should be used in laying the laterals, or else there will not be even distribution. There should not be any trees nearby, as the tiles will become completely stopped up with roots. As bacterial action is best near the surface of the soil, it follows that the pipes should not be deeper than necessary to place them beyond disturbance and severe frost.

The next step in the development of treatment of sewage on land was the application of a dose of liquids completely over the surface of small fields, instead of distributing the flow in ditches or furrows between vegetation. These areas were plowed, harrowed and leveled and surrounded by embankments to prevent a possible overflow. When natural drainage was good no underdrains were provided. But when natural drainage was not so good adequate underdrains made the areas quite serviceable provided the soil was kept clean, well loosened and intermittently dosed.

Intermittent Sand Filter

We have now come to the more highly developed type of filter known as the intermittent sand filter. Since the application of raw sewage to

sand areas is objectionable for a number of reasons, this discussion is confined to the use of these beds for handling tank effluents or sewage from which the coarser suspended solids have been removed.

Intermittent sand filters, if properly managed, give effluents which are highly oxidized, free from suspended matter, perfectly stable, and with a very low bacterial count. They are usually designed to treat 100,000 gal. per acre per day.

Sand filters originated in England perhaps a hundred years ago, and since that time they have been extensively employed in that and other countries. It was largely due to the work of the Massachusetts State Board of Health that the process of intermittent sand filtration was brought to a high degree of development, and for years the annual reports of that body have contained valuable information and data concerning sand filters and the results of their use.

Wherever cheap sandy areas have been available, intermittent sand filtration has been considered a very acceptable method of sewage purification, and at one time in New Jersey any sewage effluent discharging into a source of water supply was required to be the equivalent of that from a sand filter.

Notwithstanding the fact that this process gives an effluent the characteristics of which are almost ideal, the cost of such treatment is prohibitive for large quantities of sewage because of the expense of the area of ground necessary and the sand required for the filters. Often in the neighborhood of cities a suitable site of sufficient area is not to be had at any price. Under those conditions other methods of treatment, some of which require one-tenth or less space, must be adopted.

If a natural sand area is available, then the only thing to do is to adjust the installation to local conditions; but wherever artificial beds are constructed, several factors should be carefully considered. The size of the sand is important, as it has a direct bearing upon rates of application, free drainage and aeration. Fine sand gives an effluent with a low bacterial count, but unless very small doses are applied, with long periods of rest between, the substances in solution will not be oxidized, and a putrescible effluent will result. On the other hand, coarser sand will give non-putrescible effluents at higher rates, but at the expense of bacterial reduction. An effective size of 0.25, 0.3, or 0.4 mm., therefore, becomes a matter of choice. The sand should, however, be as homogeneous as possible, with a low uniformity coefficient and not stratified in layers, except, perhaps, around the underdrains where gravel or fine stone may be placed. Stratification interferes with the proper aeration of the bed, and a coarse layer overlying a fine one results in a clogging which is difficult of removal. For this reason new or cleaned sand should never be put on a dirty bed. The bed should be first scraped down to clean material and then clean sand applied. Care should be used to exclude, if possible, all fine dirt or clay material, as such substances very seriously obstruct free drainage and aeration.

As the bulk of the purification is done in the upper layers of the bed, a depth beyond two or three feet is hardly justifiable. Still, a deeper

bed can be cleaned more times before it becomes necessary to replace the sand than can a shallow one.

The underdrainage of sand filters is very important and although no set rule can be given for spacing underdrains, enough must be provided to insure a complete and rapid removal of the water as fast as it can get through the sand. There must be no obstruction to the flow into the drains nor away from them. They should not discharge into marshy ground nor under water.

Even distribution over the bed is also of particular importance or else parts of the bed will not do any work while the rest of the bed will be seriously overworked. Thus the capacity is reduced and an imperfect effluent results.

Since the bed must be kept in a porous condition to admit the sewage readily without ponding, it follows that some system of wooden troughs or tiles should be provided to distribute the dose quickly and evenly over the entire bed. Furthermore, it is important that the dose be quickly applied and at the end of the dose the valves or gates must cut off sharply and completely without any leaks or dribble. Such a drip or dribble will keep a portion of the bed wet and hence will prevent proper aeration and induce a growth of troublesome organisms. The better plants have effective automatic siphons or other apparatus to provide for proper dosing as well as the necessary rotation of the beds. Leaky gates operated by hand are not desirable.

Remember this: Sand filters are by no means "fool proof" and unless operated in a careful and intelligent manner they may become a source of nuisance and a total failure.

The successful management of sewage sand filters depends upon the fact that they must be operated strictly in accordance with the natural laws which underlie the process. In every case failure is traceable to the violation of one or more of the fundamental principles, and the plant attendants have almost invariably believed that the beds were for the sole purpose of straining out the suspended matter. Too often the term "intermittent" in its proper sense is entirely overlooked. Since the process is one of oxidation it necessarily follows that the doses must be applied in small quantities for short periods of time, and the beds allowed to drain and air between applications. The continuous application of sewage to sand beds for over 24 hours at a time will have serious effects upon the effluent, and will so injure the beds that a very abnormal length of time will be required for the beds to recuperate. No bed should be used longer than a day at a time and it would be much better in many cases to change the flow twice a day, especially in warm weather. When automatic dosing apparatus are used the successive charges should go upon separate beds in rotation, except perhaps in the case of small plants in which the bed will have time to drain and air before the next dose has accumulated. Even under such conditions it would, perhaps, be better to have a greater number of smaller units so that the dose would not be held so long as to get foul before being applied to the sand.

The chemistry and bacteriology of sand filters are more or less discussed in treatises on sewage disposal; but the attendant should realize that important chemical changes must be produced in the organic substances passing through the beds. These changes will not occur in sterile beds nor in those in which the proper kinds of organisms have not been allowed to develop or thrive.

The organic substances are oxidized, nitrogen appearing in the form of nitrites and nitrates, and carbon and hydrogen as carbon dioxide and water. The organisms necessary are sensitive to their environment and their activities cease if they are deprived of air or interfered with by anaerobic conditions. It therefore becomes necessary for the attendant to see that the sand bed gets an even dose of sewage of short duration, and a sufficient period of rest before the next application, for the process is not merely one of straining out the suspended matter.

The bed must dry, especially on the surface, at frequent intervals, and preferably between applications. Unless this is done very objectionable growths of fungi, blue-green algae, or green algae are bound to occur. These growths cause undue clogging of the surface of the sand, hinder the drying of the bed, and add considerably to the cost of cleaning. Preventative measures are by far more advisable than are curative.

Sand beds should be kept continually free from weeds and vegetation, as such things "constitute a perpetual plague." It is not unusual to see a neglected bed covered with tomato plants grown from seeds deposited by the sewage. No set rule for cleaning filters can be laid down, but the accumulations must be scraped up and removed as soon as they become sufficient to interfere in any way with the working of the beds. Nothing should be allowed to retard the entrance of the water into the sand. Under normal conditions the layer of deposits cracks and curls as it dries, so that it can be removed easily without taking up much sand. When large areas of natural soil are employed it is usually only necessary to plow and harrow the ground at frequent intervals. In artificial beds, a plow, cultivator, harrow or any other suitable implement may sometimes be used to good advantage after the surface deposit has been removed. It is also well to leave the surface as flat and smooth as possible in order to facilitate cleaning without removing much sand.

The winter management of sand beds in cold climates requires judgment and forethought on the part of the attendant. The Brockton method is to throw the bed up in furrows and then, at the beginning of a cold snap, to flood the bed so that the sand does not freeze, allow the water to freeze over and then work the bed in the furrows under the layer of ice resting on the ridges. When the beds are not ridged in cold weather care must be taken to prevent the sand from freezing to such a depth that the next dose will not thaw it out. Furthermore, should a layer of ice form, it must not be let down upon the surface of a flat bed and allowed to freeze fast or else the bed will go out of business until warm weather. The Worcester method of scraping the surface into little piles on the beds when cleaning in the autumn has merit in that

the top of the bed is left flat while the piles form a support for the ice, and the cost for subsequent cleaning is less than that of furrowed beds.

Winter operation must be somewhat different from that in summer. Higher rates often have to be employed and longer rests given to the beds. Under those conditions the effluents are not likely to be as good as in summer; yet with sufficient area and proper management very good results can be obtained in cold weather. During cold weather large doses should be applied suddenly in order to thaw out the frost, for a slow discharge is likely to freeze as it spreads over the bed. In some cases it will be well to cut off the distribution system, and direct the flow under the ice in a sufficiently large stream to prevent freezing. In very cold weather it is well to use only a few beds, adding others whenever a sufficiently warm spell occurs, and resting some which have been overworked. In regard to these points much will depend upon the attendant's knowledge of the local weather conditions, his foresight and good judgment.

The foregoing has been taken largely from the writer's book on the operation of sewage disposal plants and, although the book was published thirty years ago, the principles of the processes are unchanged today.

After considering all of the above discussion the fundamental requirements for sewage sand filters may be summarized as follows:

1. Intermittent dosing.
2. Adequate distribution.
3. Free and complete drainage.

BARK FROM THE DAILY LOG

By Walter A. Sperry

Superintendent, Aurora Sanitary District

July 6—Thanks to the house organ of the Clay Products Association, we have a new picture for the office. It is a cartoon which never fails to bring a smile to all those who come with the necessary $40.00 to sign up for a sewer connection permit. The cartoon shows a man ramming home the plunger of a dynamite detonator as the old privy goes into the air as a conglomeration of two-holer slab, mail order catalog and crescent-holed door. The lady of the house is explaining to a Neighbor "Now that we have a sewer system my husband is giving in to a life long ambition!"

July 12—A visit from the foreman of the transformer department of the local power company, who called this morning to inquire as to how he might dispose of a vat of spent okonite—an insulating material which is applied in the reconditioning of transformers. He was in doubt as to the advisability of discharging it into the sewer but disliked the prospect of having to haul the material to the dump. We advised him, much to his relief, that the okonite could be wasted slowly to the sewer without harmful results.

What about it? Such thoughtfulness on the part of industry is sufficiently uncommon to merit mention. We appreciated the advance notice and opportunity to advise in the disposition of this doubtful waste.

July 15—Picked up a sheet of galvanized iron on the way to the plant this morning. A pair of snips, a rivet set and a soldering kit can transform this material into many interesting and useful plant gadgets. It is suggested that you keep a sheet on hand as we do.

Our latest idea is an octagonal pan with a hole and collar to fit into the sampling opening of the wet well, where the clarified sample of sewage is taken for the laboratory. The pan looks neat and protects the floor from spillage—an obvious improvement that we should have thought about long ago.

July 18—Our plant water supply comes from a spring which yields excellent water. A long collecting gallery made of concrete blocks and having a removable slab cover delivers water through several hundred feet of pipe to the pump well. Heretofore, the supply has failed about once a year because of willow roots which would grow into a solid mass 10 to 14 feet long in the supply line where it leaves the collecting gallery. It would then be necessary to use a portable pump to lower the water sufficiently to permit the roots to be removed—a full day's chore.

Last fall we applied a bit of common sense in the form of a soil pipe, nipple and ell which was placed at the inlet end of the pipe in such a way that the opening was accessible from the surface. The gallery was opened for inspection yesterday and the pipe was found to be entirely free of roots. And so another disagreeable job passes into limbo.

July 27—Four troubled Carmelite Fathers from Procopius College were visitors today. A small sewage treatment plant, similar to the Aurora plant in principle, was under construction at their institution and they were concerned because of their lack of knowledge as to its operation. A special effort was made to explain the fundamentals fully, and our satisfaction in the resulting easing of the minds of the visitors was somewhat beclouded by the fear that they left with an exaggerated idea of our own knowledge. No doubt they will return for further consolation and advice at the first sign of trouble in the new plant.

July 30—It is sometimes necessary to improvise on the opportunity of the moment. The readers of this column would have enjoyed a candid picture of your Logger when he went out to the weather kiosk to read the thermometer this morning. Upon unlocking the door, a swarm of unhappy and hostile paper wasps confronted us on a combat mission, in the face of which we beat a hasty retreat to the laboratory. Here we donned armor in the form of a paper bag, into which eye holes were torn, and a pair of cotton gloves, after which we sallied forth to an overwhelming victory over the invading host—an effective but somewhat undignified performance.

August 3—The March, 1945, column of this Log describing the rebuilding of our sludge meter and our interest in zinc metallizing of certain parts of it for protection against corrosion. This discussion resulted in an interesting

exchange of letters with Superintendent T. R. Lovell at Marshalltown, Iowa, which exchange of information, we were informed, has resulted in the purchase of complete metallizing equipment for use in the Marshalltown plant. This was said to be the first purchase of such equipment in the sewage works field and we offer our sincere congratulations, tinged somewhat by envy, to Mr. Lovell.

Later, there was an opportunity to confer with a representative of the manufacturers of the equipment and we were amazed at the surprising number of applications for metallizing in the protection of metal equipment. Any metal that can be made into wire can be applied as a metallic coating and zinc, lead, tin, copper, nickel, aluminum, bronze and stainless steel are among those presently available. It was stated that anyone can learn to use the equipment in a few hours. The process and its applications appear to be well worth investigation and there will undoubtedly be great interest in the Marshalltown experience.

August 10—All of the queer things do not happen in Aurora. The morning mail included a note with a clipping from the May 17 edition of the Atlanta (Georgia) **Constitution.** The clipping reads as follows: "During the past two weeks 27 beef cows have been slaughtered inside the city limits of Atlanta and their 'fifth quarters' heads, hooves, entrails and tails dumped into the city sewage channels . . . on May 6, four 'fifth quarters' arrived at the disposal plant; on May 9 eight arrived; on May 11 two more were found; on May 12 three and yesterday 10 were caught in the gates leading to the sewage grinders. The entire procedure of operation at the city disposal plant has to be interrupted when beef remains are caught in the gates. The 'fifth quarters' will not pass through the small slots; they are too large for the grinders and cannot be disposed of by treatment as ordinary sewage. The entrails have to be trucked away and burned. . . ." Chester Bowles, National Administrator of O.P.A. is quoted as stating that "This is the first time that this means of disposal of evidence of black market slaughtering has come to our attention."

August 13—Chapter five of the Paper Mill story. In the last chapter, average results of laboratory tests were reported through December 3, 1944. From that date through March 10, 1945, there was a further reduction in losses amounting to nearly 50 per cent. The average suspended solids in the wastes dropped from 1,460 to 1,270 p.p.m., or 13 per cent. The average flow of the wastes decreased from 1.25 to 0.67 million gallons per week, or 46.4 per cent. The average fiber loss dropped from 7.3 to 3.6 tons per week, or 50.7 per cent. The improvements over this period were directly the result of more careful operations in the mill, as prompted by the revelations of the laboratory analyses. Such operation could just as well have extended back over many prior months with corresponding savings.

During the week of March 10, a new save-all was placed into service in the mill. Tests have not yet been made but it is anticipated that the average suspended solids content of the waste may be reduced to 700 to 900 p.p.m. if all of the waste waters are collected for treatment at the save-all. Such an arrangement has been promised. (To be continued.)

August 16—Captain Donald E. Henn, of the Army Sanitary Corps and formerly superintendent of the DeKalb Sanitary District, arrived today for a week of furlough at home. Captain Henn is now stationed at Ft. Myers, Florida. Fred S. Simms, formerly a trustee of the DeKalb district, is now operating the sewage works and is obtaining a firsthand idea of sewage treatment problems from the superintendent's viewpoint.

August 23—We were irked almost all of this day for no reason at all. It all began with our attempt to check the accuracy of the 18- by 36-inch low head Venturi meter which is used to measure the flows received for treatment. By measuring the distance between the counter weights which are connected to the water column floats, the head differential can be obtained for application in the Herschel formula. We got nothing at all from our efforts until it was noted that the flows given by the formula are in cubic feet per second and not in million gallons per day! No wonder we couldn't get a check!

August 31—Engaged this morning in replacing the stop planks in the filter effluent channel after flushing out the accumulation of bushels of worms that are trapped at the lower end.

Just as we finished, a car stopped at the sludge stock pile and two housewives debarked and unloaded a shovel and some baskets. We walked over to greet them and to offer a bit of advice on the best use of the sludge. During the conversation, one of the ladies suddenly looked startled, put her hand to her face, sniffed of it critically and said, "Why, what is this we are getting?" The humus she was putting into her baskets was so black and free of odor that she had forgotten (if she had ever known) that it was sewage sludge! An explanation sent them on their way, reassured and content.

INTERESTING EXTRACTS FROM OPERATION REPORTS

Conducted by LeRoy W. Van Kleeck

> Everybody ought to do at least two things each day that he hates to do, just for practice.
>
> —William James

Such as: 1. Hand cleaning bar screens,
2. Making scum soundings in a digester.

Annual Report on the Twelfth Year of Operation of the Sewage Treatment Plant of the City of Findlay, Ohio *

By Ben H. Barton, *Chief Operator*

Operator Barton puts the city officials right on the spot in his letter of transmittal attached to this report. For a letter that calls a spade a spade read the following:

* For a previous extract see: *This Journal* 15, 4, 739 (July, 1943).

Findlay, Ohio
Jan. 17, 1945

The attached annual report of operation of the sewage treatment plant for the calendar year indicates an acceptable degree of treatment but does not disclose the conditions that must be promptly corrected to assure continued acceptable treatment of sewage and garbage.

Attention has been repeatedly drawn to the need for additional digestion and sludge disposal. The plant personnel has coped with the situation by many and various stopgaps to its own disadvantage. The city officials have accepted our efforts as unfailing and in the apparent expectation that the plant personnel will always come up with each and every solution.

This letter of transmittal constitutes a formal and final notice that without added facilities for proper plant operation immediately, there are two alternatives:

1. Fill Rawson Park with digester overflow liquor.
2. Take secondary treatment out of service.

Residents adjacent to the plant site will not tolerate the first alternative and it is not expected that the State Department of Health will permit the second.

This report and notice is respectfully submitted by

Yours truly,

Ben H. Barton

While this report does not give a general description of the treatment facilities, the plant is of the activated sludge type, employing separate sludge digestion with ground garbage added at the plant to the raw sewage. The plant handles an average daily flow of 2.06 million gallons from an estimated population of 20,000.

Following are a few notes of interest or amusement from the 1944 year log:

Jan. 11. Wheelbarrow loaned last November returned with new coat of paint, as interest, no doubt.

Jan. 22. Installed bronze pipe strainers in vacuum line to the three raw sewage pumps. These have proved to be a very good investment as a time and labor saver, being easy to clean.

Feb. 15. After 11 years got all cross-connections eliminated in the pump room today. Not many left.

Feb. 29. Unplugged partially stopped sludge line from primary tank by reversing the direction of flow; removed ball valves from one pump and pumped through it with the other pump.

Mar. 27. To satisfy curiosity as to what goes on within the aeration tanks, sampling cocks were installed in the 8-in. drain lines. Daily samples have been taken from each pass of each tank since and the data are accumulating to tie in with operation results and particularly with the Findlay system of "adjusted-aeration" or stabilized-detention. Nothing momentous is expected but a lot of hitherto mysterious happenings are becoming explainable, if not completely understandable. Previously all samples were taken at the top, and we are now getting to the bottom conditions which seem somewhat different.

April 11. Spring floods. Pumping ground garbage into river. (*Abst. note: This brings up the old question of the added pollution to waterways when garbage is handled with sewage, as against sanitary fill or incineration.*)

May 16. Sewage value increased by one diamond ring.

June 14. Stoppage at high point of gas line from digester dome caused by dry, lumpy powder which ignited spontaneously. Believed to be phosphine. (*Abst note: Might also have been iron sulfide commonly deposited in gas lines and which will take fire spontaneously. Operators should be careful of possible burns or fires from this material when dismantling gas lines.*)

July 3. Purged final settling tank to remove source of rising sludge. Effective as usual.

Sept. 11. A local road contractor lost 10,000 gallons of "chip-tar" into sewer system. Diverted sewage carrying tar to river flat by sandbagging the North West St. regulator inlet. Tar plugs the bar screens completely.

Sept. 12. The guilty contractor furnished three men to dip tar off the water surface in the wet wells. Six truckloads hauled to the dump. Careful manipulation of pumps was required to keep the water level at proper elevation to permit skimming throughout the day.

Sept. 13. "Bowling Green Barney" phoned for some chlorine. Haven't used any since 1936; told Barney we used brains intead of chlorine. (*Abst. note: Operator refers to use of chlorine to control sludge bulking in activated sludge process.*)

Nov. 11. Carp leaping from river water onto outfall apron. Hundreds crowding into the plant outfall stream seeking dissolved oxygen. Seems that while the situation was acute they were able to survive. We used to aerate the river with primary treatment to keep fish alive after having to haul dead ones away by the truckload.

Nov. 29. Thermometer installed permanently in sewage force main after an epidemic of broken hand thermometers. Quite a convenience to take sewage temperatures in dry, light and warm place.

Final note: It's been a hard year to keep things going. At year end no space is available for digester overflow solids or drawn sludge. 1945 looks tougher!

Summary of 1944 Operating Data, City of Findlay, Ohio

Item	Average
Sewage flow, m.g.d.	2.06
Estimated population served, persons	20,000.0
Sewage by-passed, hrs. per month	71.0
Pounds garbage added per month	68,133.0
Grit per month, cu. ft.	92.0
Skimmings per month, cu. ft.	46.0
Screenings per month, cu. ft.	56.0
Blanchard river data:	
Dissolved oxygen, p.p.m.:	
Above plant	4.9
Below plant	4.6
5-day B.O.D., p.p.m.:	
Above plant	16.0
Below plant	18.0
Activation data:	
Air per gal. sewage, cu. ft.	.83
Returned sludge, per cent	31.2

Summary of 1944 Operating Data, City of Findlay, Ohio—Continued

Item	Average
Returned sludge, suspended solids, p.p.m.	4,841.0
Mixed liquor, suspended solids, p.p.m.	1,439.0
Mixed liquor, solids by volume, per cent	18.2
Final effluent, dissolved oxygen, p.p.m.	5.1
Sludge index, Mohlman	126.0
Detentions:	
Detritor, min.	2.33
Primary settling, hrs.	4.29
Secondary aeration, hrs.	6.2
Secondary settling, hrs.	3.2
Sludge digestion, days	58.3
Analytical data:	
Suspended solids, p.p.m.:	
Raw	350.0
Settled	92.0
Final	12.0
5-day B.O.D., p.p.m.:	
Raw	423.0
Settled	160.0
Final	22.0
Settleable solids, ml. per liter:	
Raw	19.5
Settled	0.5
Final	0.3
Overall reductions in per cent:	
Suspended solids	96.5
5-day B.O.D.	95.5
Settleable solids	98.9
Volatile solids by digestion	60.9
Raw sludge data:	
Thousand gals. per month	320.6
Dry solids, per cent	3.38
Volatile solids, per cent	75.9
Digested sludge data:	
Thousand gals. per month drawn	36.5
Dry solids, per cent	4.37
Volatile solids, per cent	55.4
Overflow liquor, per cent solids	1.82
Gas production, cu. ft. per lb. volatile solids dest.	15.85
Cost of treatment:	
Per m.g.	29.81
Per capita per month	0.09
Per 1,000 lbs. B.O.D. removed	9.45
Gas engines, hrs. per month operated	560.0

Annual Report of the Worcester, Mass., Bureau of Sewers for the Year 1943 *

By John H. Brooks, Jr., *Superintendent*

Prevailing war conditions have logically curtailed the several operations of the department. This situation is more particularly reflected

* For previous extracts see: *This Journal*, **10**, 1075 (Nov., 1938); **13**, 1244 (Nov., 1941); **17**, 357 (March, 1945).

in the expenditures for new sewers. The total net expenditures of the department for the fiscal year were $337,166.27. The total man hours of the department was 241,352, a decrease of approximately 42,000 from 1942 and 124,000 from 1941.

The present personnel of the Bureau of Sewers consists of 103 permanent employees who, with a few exceptions, have been in the service for twenty years or more.

The total miles of sanitary, surface and combined sewers to 1944 is 428.635. The total expenditures for the maintenance of the public sewer system totalled $85,020.75, an increase of approximately 16 per cent over the preceding year. The principal activities were concerned with the repair and cleaning of sewers and the yearly program of catch basin cleaning. A total of 5,544 catch basins were cleaned during the year with the removal of 11,645 cubic yards of materials.

With the completion of the Webster St. pumping station there are now five distinct pumping districts from which the respective pumping stations raise the sewage to the gravity system. All of the stations have operated with a minimum of difficulty.

At the sewage treatment plant, two unusual conditions which affected the efficiency of the treatment of sewage were present practically throughout the year: (1) an abnormal increase in the acidity of the raw sewage with its attendant increase in acidity of the trickling filter influent and (2) a prolonged period of heavy growth on the surface of the trickling filters.

Investigations revealed the sources of this acid condition to be the discharge of acid waste liquors from certain wire and metal trade industries. Further investigations are in progress and it is planned to adopt corrective measures.

Description of Sewage Treatment Works

The plant consists of the following treatment units: grit chambers, bar screens, Imhoff tanks, dosing tanks, trickling filters, secondary settling tanks, sludge drying beds. The plant was constructed from 1919 to 1925 and was placed in operation on June 25, 1925. It was designed by the Engineering Department of the City of Worcester for a population of 242,000 and an average flow of 28 m.g.d. and constructed at a cost of $4,130,000. The cost per m.g.d. capacity was $147,500 and the cost per capita was $17.07.

Imhoff Tank Operation

Interesting facts concerning Imhoff tank operation are:

(1) The quantity of sludge produced totalled nearly fifteen million gallons.

(2) The pH of the sludge dropped from 6.9 during the first three months of the year, to from 6.0 to 6.7 during the remainder of the year; the average pH was 6.5.

(3) Despite the more acid condition of the digested sludge, the digestion of the sludge has continued in the usual manner. It is possible

that about 3.5 per cent iron in the dried solids of the sludge has been an aid to the digestion process.

Increased Acidity and Iron Content of the Sewage

Investigation of the increased acidity of the sewage showed that the acidity and the iron (Fe) content of the sewage were independent of one another. The explanation lies in the extent to which pickling liquor baths are used before the spent acid is emptied into the sewer. The increased amount of free acid discharged in these waste liquors was explained by one industrial executive as a natural result of piece-workers endeavoring to increase their production and thereby, their compensation. Presumably, industry might claim that the increased value of production was considerably greater than that of the unused acid.

The average iron content of the sewage during 1943 was 35.3 p.p.m., a quantity much less than that contained in the sewage from 1927 to 1930, inclusive. However, during August, September and October, 1943, when the iron content of the sewage and filter influent was a matter of great concern, the quantities contained in the sewage were 45.0, 64.5 and 49.0 p.p.m., respectively.

Past experience has demonstrated that increased iron content of the filter influent adversely affected the efficiency of filter operation, but in this instance, it is evident that increased acidity of the filter influent produced a far greater deterioration of quality of the effluent.

Operating Data for 1943, City of Worcester, Mass.

Item	Average
Estimated population connected	185,000.0
Sewage flow, m.g.d.	23.91
Sewage flow, max. day, m.g.d.	52.9
Sewage flow, min. day, m.g.d.	13.04
Total cost of operation, dollars	55,878.74
Cost per capita, cents	28.9
Cost per capita connected, cents	30.2
Cost per m.g. sewage	6.40
Grit, total cu. yds.	750.1
Cu. ft. per m.g.	2.32
Total tons	787.6
Chambers cleaned, no. of times	7.0
Cost of removal per cu. yd.	0.38
Screenings:	
Total cu. ft.	13,042.0
Cu. ft. per day	35.7
Cu. ft. per m.g.	1.49
Total tons	436.9
Cost of removal per cu. ft.	0.11
Cost of removal per m.g.	0.16
Imhoff tanks:	
Detention period, hours	2.7
Gals. wet sludge, total	14,888,384.0
Solids in wet sludge, per cent	8.18
pH sludge	6.5
Volatile matter in sludge, per cent	45.4
Iron in dry solids, per cent	3.51

Operating Data for 1943, City of Worcester, Mass.—Continued

Item	Average
Settleable solids removal, per cent	92.4
Suspended solids removal, per cent	61.9
B.O.D. removal, per cent	30.8
Trickling filter operation:	
M.g.d. flow	19.64
Acres of filters in use	12.43
M.g. per acre per day	1.58
Nozzles cleaned per day	104.0
Secondary settling tank operation:	
Sewage flow, m.g.d.	19.64
Detention, hrs.	2.1
Gals. wet sludge	6,255,000.0
Solids in sludge, per cent	4.19
Volatile matter in dry solids, per cent	48.08
Iron in dry solids, per cent	8.13
Analytical results:	
Suspended solids, p.p.m.:	
Sewage	252.0
Imhoff tank effluent	96.0
Trickling filter effluent	100.0
Secondary tank effluent	53.0
Per cent removal, entire plant	79.0
5-day B.O.D., p.p.m.:	
Sewage	143.7
Imhoff tank effluent	99.5
Trickling filter effluent	30.5
Secondary tank effluent	26.0
Per cent removal, entire plant	82.0
Iron, p.p.m.:	
Sewage, total	35.3
Sewage, dissolved	18.0
Imhoff tank effluent, total	16.4
Trickling filter effluent, total	27.0
Trickling filter effluent, dissolved	5.7
Secondary tank effluent, total	17.6
Secondary tank effluent, dissolved	4.7
Relative stability, per cent:	
Trickling filter effluent	62.0
Secondary tank effluent	68.0+
Cu. yds. sludge cake removed	20,527.0
Total cost of sludge cake removal	12,363.07
Cost of sludge cake removal per cu. yd., cents	60.2

Annual Report of the Tri-City Sewage Treatment Plant (Pasadena, Alhambra, South Pasadena, California) for the Fiscal Year July 1, 1943, to June 30, 1944

By William A. Allen, *Superintendent*

Aeration and Clarification

There have been periods during the year when the quality of the effluent has been lower than is considered desirable. During these pe-

riods additional chlorine has been applied to the effluent and in some instances it has been deemed advisable for the Crown City Ranch temporarily to discontinue irrigation.

Sludge Disposal

Delivery of the excess activated sludge to the facilities of the Los Angeles County Sanitation Districts continues to be a very satisfactory method of sludge disposal.

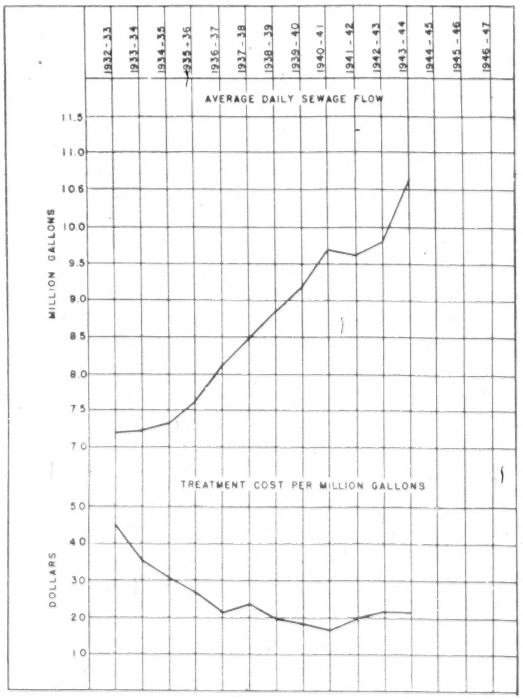

FIG. 1.—Comparison of sewage flow and treatment cost at Tri-City Sewage Treatment Plant.

In December, 1943, a change in operating procedure was made which utilized the Currie Unit to obtain a greater concentration of the waste sludge without affecting the remainder of the plant. As a result of this change we are now delivering 2 to 3 million gallons less sludge per month to the Los Angeles County Sanitation District plant. The saving effected, seventy to one hundred dollars per month, just about compensates for the additional sludge disposal cost due to increased sewage flow.

General

From the experience during the past year with increased flows it is quite apparent that as soon as satisfactory construction materials are available it will be necessary to provide additional capacity to relieve the overload on the existing units. It is of interest to note that the sewage flow is now equal to that estimated for 1958–60 in the Greeley and Hansen report. Increased population, increase in number of manufacturing plants and volume of production, and the trend towards higher per capita contribution to the sewerage system are undoubtedly the main reasons for the rapid increase in sewage flow.

Maintenance during the year has been limited to that necessary to keep the plant equipment in operable condition. It was necessary to take some of the aeration tanks out of service for cleaning and, in some instances, to renew the porous plates. A considerable amount of plate renewal will be necessary when materials and labor are more plentiful for civilian purposes.

Summary of 1944 Operating Data, Tri-City Sewage Treatment Plant, Pasadena, Alhambra and South Pasadena, Calif.

Item	Average
Total population of area served	162,810.0
Population connected to plant	155,083.0
Sewage flow, m.g.d.	10.6
Operating cost, dollars	82,287.87
Cost per m.g.	21.22
Cost per capita connected, cents	54.4
Air used per gallon sewage, cu. ft.	1.55
Excess sludge, million gals., total for year	122.69
Chlorine used, lbs. per day	174.0
Chlorine used, lbs. per m.g.	16.4
Analytical results:	
5-day B.O.D., p.p.m.:	
Raw sewage	147.0
Main plant effluent	15.5
Currie unit effluent	12.5
Per cent reduction, main plant effluent	89.4
Settleable solids, ml. per liter, 30 min.:	
Raw sewage	9.7
Main plant effluent	0.56
pH:	
Raw sewage	7.3
Main plant effluent	7.9
Suspended solids, p.p.m.:	
Raw sewage	282.0
Main plant effluent	25.0

Annual Operation Report on Sewerage and Sewage Disposal for the Village of Rockville Centre, N. Y.*

By C. George Andersen, *Superintendent*

General Information on Plant

The sewage treatment plant units include: prechlorination, basket screens at three pumping stations and a comminutor at fourth pumping station, primary sedimentation, pre-aeration, so-called modified activated sludge as developed at Rockville Centre and practiced since 1934, continuous withdrawal of excess activated sludge by pumping to concentration tanks as practiced since 1932, secondary sedimentation tanks and post-chlorination. Clarification of plant effluent by mechanical vacuum filter was discontinued in May, 1942.

Effluent discharge is to a tide water estuary.

The design capacity of the plant is 2.0 m.g.d. for a population of 20,000. The plant has been for many years operating most efficiently with flows upward of 3.0 m.g.d., due to our operating methods. In 1933 mechanical vacuum filters for clarifying the activated sludge effluent were built, but the operation of these has been suspended since May, 1942, due to the efficiency in clarification of the activated sludge treatment.

Sewage Screening

At the pump stations baskets with 2-inch clear openings, square mesh, are used for screening. The baskets are cleaned once daily. Screenings are disposed of at the village incinerator.

Primary Sedimentation Tanks

The sludge mechanism is operated on all three tanks 24 hours daily. To insure concentration of the sludge drawn, the drawing is made at least three times during the 24 hours.

Secondary Sedimentation

Excess sludge is taken off the return sludge pump under pressure and discharged to decanting tanks located a few feet from the point of sludge return.

Chlorination

A policy of prechlorination is practiced at the pumping stations for odor control and to bring about suspension of septic action in the sewage before reaching the treatment plant. There is no residual chlorine in the sewage entering the plant. Chlorine is applied in the plant at the secondary clarifier discharge. A chlorine residual of 2 p.p.m. is maintained in the plant effluent. Chlorine residual tests are made every hour and any variation from the 2 p.p.m. residual is immediately corrected.

Aeration Tanks

Sludge bulking in the final tanks has not been experienced in ten years.

* For a previous extract see: *This Journal*, **16**, 169 (Jan., 1944).

Sludge Digestion Tanks

Control of digestion is by pH, temperature, depths of sludge, solids and volatile matter determinations, and also by the concentration of sludge before pumping to digesters. Another factor in an activated sludge plant is the breaking down of aerobic conditions in the excess sludge before introducing it to the digesters. In our case this is done by a good mixing with primary sludge and a holding time before pumping. Lime is always added during pumping to maintain pH and give stable conditions. The ratio of the accession of raw sludge (organic) to the seed or digested sludge has averaged 1:14. The theoretical allowable proportion for controlled tanks is 5 per cent; our average daily has been 7 per cent.

Summary of 1944 Operating Data, Rockville Centre, N. Y.

Item	Average
Estimated population served	20,400.0
Sewage flow, m.g.d.	2.28
Employees for plant and for sewer maintenance	13.0
Screenings, cu. ft. per m.g.	1.1
Primary settling tank data:	
Number of tanks	3.0
Detention at 2.28 m.g.d., min.	47.0
Sludge per month, cu. ft.	22,215.0
Sludge solids, per cent	4.1
Sludge, cu. ft. per m.g.	322.0
Skimmings per month, cu. ft.	73.0
Cu. ft. per m.g.	1.0
Settleable solids, ml. per liter, 1 hr.:	
Influent	8.6
Effluent	3.1
Secondary settling tank data:	
Number of tanks	2.0
Detention at 2.28 m.g.d. plus return sludge, min.	109.0
Suspended solids, p.p.m.:	
Effluent	21.0
Relative stability, effluent	89.0
Chlorination, lbs. chlorine per m.g.	131.0
Plant effluent residual, p.p.m., min.	2.0
Aeration tank data:	
Number of tanks	
Detention, sewage plus return sludge, hrs.	4.25
Air, cu. ft. per gal.	1.2
Power, k.w. per m.g.	397.0
Sludge to sewage ratio, per cent	4.0
Settleable solids, ½ hr., per cent	6.1
Suspended solids, p.p.m., mixed liquor	891.0
Volatile suspended solids, per cent	92.0
Suspended solids, return sludge, p.p.m.	23,542.0
Excess sludge, solids, per cent	3.3
Sludge index, Mohlman	56.0
Sludge index, max. av.	89.0
Sludge index, min. av.	29.0
Sludge digestion tank data:	
Number of tanks	8.0
Temperature maintained, °F.	85.0

Summary of 1944 Operating Data, Rockville Centre, N. Y.—Continued

Item	Average
Sludge pH	7.3
Sludge depth maintained, ft.	10.3
Lime used per month, lbs.	6,973.0
Heating water temperatures, °F.:	
*In	169.0
*Out	158.0
Sludge drawn per month, cu. ft.	7,538.0
Sludge, solids, per cent	5.7
Sludge, volatile solids, per cent	52.0
Supernatant, B.O.D., p.p.m.	175.0
Sludge drying bed data:	
Number of beds, glass-covered	7.0
Wet sludge depth, inches	4.8†
Sludge drying time, days:	
Average	14.0
Maximum	16.0
Minimum	12.0
Sludge applied per month, cu. ft.	7,571.0
Solids in sludge, per cent	5.7
Air dried sludge, cu. ft. per m.g.	10.5
Solids, per cent	42.1
Vacuum filter data (for sludge drying):	
Filter area, sq. ft.	505.0
Days used per month	3.0
Paper pulp used, lbs. per lb. dry solids‡	1.0
Thickness of cake, ins.	3/8
Filter cake, dry solids, per cent	21.7
Dry solids (lbs. per sq. ft. per hr.)	0.8
Filter cloth (60 × 40 mesh bronze), hrs.	500.0

* Abs. note: A case of coil incrustation?

† A figure of 8 ins. is given elsewhere in report.

‡ No conditioning chemicals are used.

Sludge gas collection data:	
Gas produced daily, cu. ft.	15,701.0
Gas produced per capita daily, cu. ft.:	
Average	0.8
Maximum	1.0
Minimum	0.7
Sewage analyses:	
B.O.D., p.p.m.:	
Raw	301.0
Primary tank effluent	165.0
Final tank effluent	25.0
Suspended solids, p.p.m.:	
Raw	351.0
Primary tank effluent	174.0
Final tank effluent	21.0
Dissolved oxygen, p.p.m.:	
Plant effluent	3.9
Cost data:	
Cost original plant (excl. percolation beds)	$350,000.00
Cost sludge filtration units	61,000.00
Cost per m.g. (based on 2.28 m.g.d.)	187,200.00
Total cost for maintenance and operation	42,918.18
Cost per m.g. for maint. and operation	51.52
Cost per capita for maint. and operation	2.10

TIPS AND QUIPS

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Imaginary Tales from Toronto, where the Eighteenth Annual Meeting of the Federation *would have been held* as a convention of the membership-at-large had it not been for the fact that war transportation comes first . . . a registration, spiritually speaking, of 3,200 (every member *wishes* that he might have been there, doesn't he?) . . . the usual outstanding technical program arranged by Chairman Gilcreas and his Publications Committee (this, at least, is fact!) . . . a deliriously happy Arthur T. Clark with every Associate Member of the Federation participating in a record breaking exhibit (he can dream too, can't he?) . . . the beautiful Hotel Royal York, with rooms to spare and no lines to stand in (getting worse, isn't it?) . . . an entertainment program including Bob Hope, Bing Crosby, Lauren Bacall, and Gypsy Rose Lee (might as well make it worth while!) . . . an inspection trip—by plane—of every sewage treatment plant within 500 miles of Toronto (now we *are* getting up in the air!) . . . a ladies' entertainment climaxed by an inspection trip to a hat shop, with every lady permitted to take home the exhibit of her choice with the compliments of the management (which just about tops everything) . . . thick, juicy steaks at every meal—and butter, too! . . . a pleasant drive home in that shiny new car (with tires) via Niagara Falls, New York City, Washington and Miami . . . but, getting back to earth again, the meeting in Toronto, whenever it is held, will be one to be long remembered. The Canadian Institute on Sewage and Sanitation was primed to entertain the Federation royally this year and the unavoidable postponement of the 1945 Convention will not dim the luster of its future plans. There is much satisfaction in being able to look forward to this event, perhaps in 1946.

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The Federation's first manual of practice, "Occupational Hazards in the Operation of Sewage Works," was highly complimented recently when Dr. J. Lynn Mahaffey, Director of the New Jersey Department of Health, made it the subject of a timely letter to all sewage works operators in the state. In directing attention to the manual, Dr. Mahaffey offered the services of the personnel and equipment of the department's Bureau of Industrial Health in surveying sewage treatment plants and sewerage systems for general atmospheric pollution and for special sampling studies at suspicious points. This service is a commendable supplement to the recommendations contained in the manual in regard to noxious gases and vapors. Divisions of industrial hygiene in other states would do well to follow New Jersey's leadership.

The safety manual has established an enviable record for its successors. Six thousand copies have already been distributed and an ample supply is still on hand. Every sewer crew foreman and treatment plant operator should be supplied with a copy for study and reference.

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"Sewage Disposal Around the World" was the theme of the June, 1945, News Broadcast of the New York State Sewage Works Association. The issue featured letters from military members who have seen service all over the globe. A few excerpts:

From Col. W. A. Hardenburgh, Director of the Sanitary Engineering Division of the Sanitary Corps:

"At the former (Newfoundland), we have a modern U. S. type settling tank and filter. At the various South American bases, we don't have much—usually some sort of a settling tank and in places a poor variety of sand filter. In Africa, we generally use local sewers or sewage-carrying ditches, but convey the sewage well beyond the limits of our camps in good old U. S. sewers. We have felt these practices were permissible because what we have done, inadequate as it may be when viewed by American standards, is generally far superior to local methods. . . ."

From Capt. Stanley Barker (C. E. C.), U. S. N. R., stationed in Peru:

"Practically speaking, there is no treatment of sewage in Peru. Possibly, some communities settle part of the sewage before discharging it into irrigation ditches or stream beds but such communities are few and far between and, generally, the sewage, when there are sewers, is conducted to the nearest *acequia* (irrigation ditch) or stream bed (which will probably be dry 6 months of the year). In Lima and its suburbs, where there is a reasonably complete system of sewers, the sewage reaches the ocean by multiple outlet sewers and only recently is there being developed a project to intercept these outlets and carry the sewage out into deep water by a single outfall.

"Nuisance conditions due to lack of sewage treatment are not as bad as would be the case in a more densely populated area, though occasionally the sewage creates a swampy condition in certain area which encourages mosquito breeding."

From Lt. Col. R. C. Sweeney, at Paris, France:

"In all of French North Africa I saw just one municipal plant, a plain settling tank and contact filter in an Algierian town south of Algiers. In Italy I also saw a sedimentation plant northeast of Naples—it was being bypassed. To date in France I have seen only one plant—a large institutional plant now serving a U. S. hospital. It is a modern activated sludge plant designed for 2,200 people, now serving about 5,500. You can imagine what is happening. The plant has separate sludge digestion with one feature that was new, at least to me, although other plants have probably used the idea. The plant was provided with a gas circulating pump or compressor which took gas from the top of the digester and pumped it back into the bottom to provide for the mixing and stirring of the contents. None of the large cities where I have spent most of my time, Algiers, Naples, Marseilles, Dijon or Nancy, have had treatment plants. Paris, of course, does have a number of plants and disposal arrangements ranging from sedimentation with disposal on land to relatively new activated sludge plants. I haven't seen them yet though they are on my 'must' list along with the Follies Bergeres."

From Capt. Joseph Salvato, Jr., who served in Alaska:

"The temporary methods used by the Army for the disposal of sewage were patterned after the local practices. These consisted of the old reliable pit privy, the removable pail type privy, and cesspools or collecting tanks. Where the privy was used, it was found desirable to insulate and heat the structure to encourage its use at times of extreme cold. This proved so successful that it became a routine matter to check the privies when looking for missing personnel on work details. Where possible sewage was discharged into a large stream, either directly or through a settling tank, depending upon local conditions. During cold weather the contents from pail privies and cesspools were collected in heated enclosed tank carts 'honey wagons' and were discharged to large

streams or lakes not used for water supply. When water courses were frozen, wastes were deposited on the ice to be washed away in the spring break-up.

"More permanent methods of sewage disposal, in addition to improved variations of the units mentioned above, consisted of settling tanks, referred to locally as septic tanks, and Imhoff tanks. The effluent from settling tanks was distributed to absorption fields by means of improvised wooden box sections, agricultural tile, bell and spigot terra cotta pipe, 'blind ditches' or 'french drains,' depending upon the materials which happened to be available. A five- to eight-foot earth cover was found adequate to prevent freezing where the system was in continuous use. Effluents from Imhoff tanks, as well as those from settling tanks, were discharged to lakes or streams not used directly as sources of water supply. In places where permafrost or permanently frozen ground existed, the effluent was discharged to oxidation ponds. Very little, if any anerobic decomposition was observed taking place in settling tanks and Imhoff tanks. This was not surprising since the temperature of the incoming sewage averaged around 45 degrees and the water supply ranged from 32 to 44 degrees F. Consideration was given to the heating of Imhoff tanks and incoming sewage to improve sedimentation and accelerate digestion, but this procedure was found expensive and of dubious necessity from a public health viewpoint. In addition, tanks had been constructed of rough lumber without insulation in seasonally frozen ground having a varying ground water level at a temperature below 45 degrees throughout the year. A heavy scum blanket consisting primarily of undigested solids soon formed in the settling compartment of some Imhoff tanks and in one instance raised the floor grating six inches. The scum was disposed of by spreading out on a natural sand bed and plowing under when weather permitted. No nuisance condition was created as a result of this practice.

"Sewer lines buried eight feet below the surface did not freeze in seasonally frozen ground. In areas where it was not practical to bury the sewers because of high ground water, permafrost or topography, the lines were insulated and run on or slightly below the ground surface. A favorite method to prevent freezing was to lay welded steel water and sewer lines in an insulated wooden box culvert heated by means of specially provided steam lines.

"All material except rough lumber was transported over water and then over a narrow-gauge railroad. In some cases even rough lumber had to be brought in since timber was not always locally available. It was not unusual therefore to find a transite sewer line suddenly change to cast iron then to steel and finally end up with wire wound wood stave or even terra cotta pipe. The essential thing was to get the job done and the system in use as soon as possible, and that was accomplished."

From an unidentified writer who served in the southwest Pacific area:

"We entered Guadalcanal very early in the operation. The place was in a very primitive stage and to throw in several thousand men at one time created a bit of a problem. This problem was handled with the usual military slit trenches, a dig and cover proposition except the trenches are dug by a working party for use of all hands. A shovel is left at the trench and each man that uses the trench refills with enough earth to prevent an exposed nuisance.

"As we became more civilized we built six and eight hole privies. The first were just the box set on a platform. Drop seat covers were fashioned from wood with pins for hinges as no strap hinges were available. After about two months we really became civilized and put a roof over the facilities and provided a screened enclosure. Chloride of lime was usually not available. This shortage was overcome by throwing dry coconut husks into the pit, pouring old motor oil on them and setting the place afire. Sufficient heat was developed to kill the fly larvae and we had very little fly nuisance.

"We did, however, experience some dysentery before the heads were screened and before the galleys were screened. I always did blame this sickness on the flies as there was so much chlorine in the drinking water it must have been safe. One couldn't blame the milk supply as there was no milk supply except for a small amount of canned milk.

"You may have read about the P.T. boats knocking down the heads along the shores of some of the islands. At Tulagi we had some of these privies on stilts over the water. They were very practical and seemed to work without maintenance or worry. Twice each day the tide carried away all deposit leaving almost no pollution on the beach. As you may well imagine one of those heads on stilts was no safe place to view the scenery when fast boats were passing. Several did collapse from the force of the waves. Many small fish frequented those places and it was interesting to see the various colors and shapes. Some were really very pretty.

"We were not able to provide better sewage disposal because of the scarcity of pipe of any kind. Water was pumped from the river, chlorinated and delivered by tank trucks. There was almost no water under pressure. There could not be water carried sewage under those conditions so more elaborate systems were out of the picture. The chemical or septic type of disposal was out because of lack of materials and chemicals.

"We did have a marked success treating galley wastes in ordinary grease traps. The traps built had a capacity of about one and one-half gallons per person contributing to the trap. They were cleaned about every two months and the grease buried. One particular trap I know of was made of two inch planks with no bottom. This trap was serving faithfully after seventeen months."

And, finally, from Major Harley N. Riley, in Germany:

"If I ever saw complete treatment, they (the Germans) sure have it. One very popular by-product not used anywhere else that I know of is the extensive use of the gas from the digestion plants for the operation of motor vehicles. They have very elaborate bottling plants for that purpose."

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Dr. Karl Imhoff, eminent German engineer, has come safely through the European war. A V-mail letter from Major M. W. Tatlock (formerly of Dayton, Ohio) to C. K. Calvert of Indianapolis, contains the following: "Dr. Imhoff's many friends in the U. S. will be relieved to know that his family, home and library are unscathed by the war."

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Governor Ralph F. Gates of Indiana has proclaimed the period of August 13 to August 20 as "Stream Improvement Week," to draw public attention to the stream pollution problem in that state and to enlist public support in its solution.

As the Governor of Indiana said to the Governors of all other states, "It's time that something be done about this matter of stream pollution!"

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The March, 1945, issue of *Sewage Gas*, published by the Environmental Sanitation Division of the Indiana State Board of Health, cites two outstanding examples of unusual public relations activity by sewage works superintendents.

At Gary, Supt. W. W. Mathews was appointed chairman of the local committee which arranged for a concert by the Chicago Symphony Orchestra, a chore which he found to be not unlike the operation of his activated sludge plant since both jobs involved the control of somewhat temperamental "organisms." At Marion, the Junior Association of Commerce honored Supt. David Backmeyer by naming him to receive its annual Distinguished Service Award for his outstanding service in civic affairs.

Public recognition of these men automatically brings favorable attention to the services they represent.

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Supt. John R. Downes of Plainfield, N. J., will not be allowed to retire as inauspiciously as he might desire from his long and faithful term of office as secretary of the New Jersey Sewage Works Association. Plans are underway to make the next annual meeting of the association an especially gala occasion and to designate it as "The John R. Downes Appreciation Meeting."

And when the "World's Oldest Sewage Works Association" plans a gala meeting, let there be no doubt but that it will be gala indeed!

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Perhaps it was an ill wind that prompted O.D.T. to ban sewage works meetings this year, but the same breeze blew some good when it started rotation of *The Windmill*, the first news bulletin of the Central States Sewage Works Association. This project had been under consideration by association officials for some time and was deemed especially worthy of initiation at this time to fill the gap left by cancellation of the 1945 annual meeting.

The Windmill is a snappy, diversified, 8-page miniature newspaper, edited in fine fashion by a Board of Editors including D. E. Dreier, M. A. Milling, G. F. Bernauer and M. L. Robins. Personal notes, news items, association affairs, feature columns, humor—even a cartoon introducing a character named Alonzo McSludge—all are blended into a bulletin that will be read with interest and enjoyment.

Congratulations and best wishes to *The Windmill!* Long may it spin!

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Buckeye Sludge, the mouthpiece of the Ohio Conference on Sewage Treatment, flows merrily on with its third issue, unhindered by thixotropy, paper shortage or dearth of newsy items and features. This sparkling newsletter has everything that it should have, in our opinion, and Editor L. B. "Barney" Barnes and his staff of feature writers (Stepleton, Turner, Wittmer, et. al.) are to be given much credit.

Good going, Buckeyes!

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Editorials

THE 1945 CONVENTION—A WAR CASUALTY

Prior to 1940, there had never been a national technical convention in the sewage works field. The series of five annual conferences of the membership-at-large of the Federation which began in that year can be credited as prominent factors in the unification and preparation of the field for unprecedented military and civilian problems incident to the war. There can be no question as to the inestimable value of these meetings.

This year, a transportation problem of infinite complexity has necessitated sacrifice upon the altar of Mars of the Eighteenth Annual Meeting and Sixth Convention of the Federation. Postponement of the convention, in complete compliance with the requirements of the Office of Defense Transportation, brings about the paramount objective that there will be no interference with the mass movement and redeployment of military forces at a critical phase of the war. Preservation of the personal comfort and convenience of those who might have attended the convention, had it been held, is another asset; there can be unqualified assurance that there is no pleasure in travel today! But there are losses, too,—both to sewage works technicians and the public service they represent—in the absence of opportunity to meet and consult with noted experts on a common ground, to exchange first hand information in detail with others having similar problems and to participate in forum discussions from which the benefits of wide and diversified experience may be derived. Fortunately, it has been possible to overcome the complete loss of a technical program by virtue of the accomplishment of the Publications Committee in assembling a noteworthy group of special papers for publication in this and subsequent issues of the *Journal*. Postponement of the 1945 convention is regrettable, but not calamitous; it is accepted in good spirit.

The technical "program" introduced by this conventionless *Convention Number* is indeed outstanding, and is deserving of the emphasis of direct verbal presentation at an annual convention. Chairman Gilcreas and his Publications Committee as well as each contributing author are here and now tendered the sincere thanks of this department—a feeling which will be echoed by all. Eleven timely papers are included, three of which are contained in this issue. A topic heretofore given little attention in the literature is discussed with authority by Nicol MacNicol of Forest Hill, Ontario, Can., in his paper "Installation and Maintenance of Sewer Connections." The review "Trickling Filters—Past, Present and Future," by E. Sherman Chase of Boston, Mass., gives a rounded picture of the development and trends in application of that popular sewage treatment device. A complete analysis of research and experience directed toward solution of a most troublesome industrial waste problem is contained in the paper "Treatment and Disposal of Spent Pickling Liquors," by Richard D. Hoak of Mellon Institute, Pittsburgh, Pa.

The activated sludge process was to be the "theme" of the 1945 convention and a series of five sterling contributions on the subject features the program. All of these papers, together with another contributed activated sludge article, have been scheduled for publication in the November *Journal*, which will make that issue a significant reference. The series will be given background and perspective by the paper "The Development of the Activatd Sludge Process of Sewage Treatment," by Samuel A. Greeley of Chicago. Exhaustive and original studies of two of the most vexing problems associated with the process will be reported in "Conditioning of Supernatant Liquors for Addition to Aeration Tanks," by Leon S. Kraus of Peoria, Illinois, and in the paper "Rising of Activated Sludge in Final Settling Tanks," by Clair N. Sawyer and Leland Bradney,

the latter work being based on observations made at Sioux Falls, South Dakota. An international flavor is imparted by the contributions "Operating Experiences at the West Middlesex (England) Activated Sludge Plant," by C. B. Townend and "Experiences with Activated Sludge at Toronto," by William Storrie.

Diversification and scope are given the program by the remaining three papers, all authored by prominent authorities. "Design of Sewers to Facilitate Flow," by Thomas R. Camp of Boston, will be of pertinent value to sewage works designers. Progress of current research on paper pulp and manufacturing wastes, now underway at Mellon Institute, will be described by Harry W. Gehm, New York, N. Y. Stream pollution control agencies will find sound guidance in the paper "Standards of Stream Sanitation," by H. W. Streeter of the U.S.P.H.S., Cincinnati, Ohio, acknowledged leader in stream pollution investigation.

When it became apparent early this year that this convention of the Federation could not be staged, the writer confesses to some concern as to the effects of the development just as the Federation is gaining its "sea legs" in its transition to a self-sustaining organization. It is already evident that such misgivings were not justified; the Board of Control will hear a heartening report on the continued growth and progress of recent years when it convenes for its Annual Meeting in October. As a matter of fact, the temporary relief of the secretarial staff from convention arrangement duties has made it possible for several previously undeveloped details of business management to be given attention—with satisfying results.

It may be taken for granted that the next convention, whenever it is held, will be one to remember. Keenly disappointed in the postponement of the 1945 conference, the Canadian Institute on Sewage and Sanitation will spare no effort in the fulfillment of its functions as host, perhaps in 1946.

SCHROEPFER JOINS MINNESOTA FACULTY

After seventeen years of service with the Minneapolis-St. Paul Sanitary District, George J. Schroepfer has recently undertaken new responsibilities as Professor of Sanitary Engineering at the University of Minnesota. Chief Engineer and Superintendent of the District since 1938, Mr. Schroepfer resigned this position in July and assumed his new duties on September 1. He had been continuously in the employ of the District since 1928, being associated in responsible capacity with the preliminary investigations, design, construction and operation of the modern sewage treatment works now serving Minneapolis and St. Paul. His resignation was accepted with highest commendation for past services rendered.

Mr. Schroepfer has always given freely of his boundless energy to activities in professional societies. He served as President of the Federation in 1942-43 and has been a leader in the Central States Sewage Works Association, of which organization he is also a Past President. He is prominent in the activities of the Northwestern Section and Sanitary Engineering Division of the A.S.C.E. and is now serving as Secretary of that division.

The ranks of sewage works operators loses an outstanding figure as Mr. Schroepfer ventures into the realm of education and research. It is safe to predict that the University of Minnesota will presently assume a position among the foremost institutions in sanitary engineering training.

Captain Kerwin L. Mick, of the Army Sanitary Corps, will succeed Mr. Schroepfer as Chief Engineer and Superintendent of the Minneapolis-St. Paul Sanitary District. Captain Mick is now on overseas military duty and will take over his new position when released from the army. Captain Mick has likewise had considerable experience on the Minneapolis-St. Paul project, his association beginning in 1931 as chemist, from which he advanced to the position of Chief Chemist in June, 1935. He is a graduate in chemical engineering from the University of Minnesota, registered professional engineer, and a Past President of the Central States Sewage Works Association.

W. H. W.

Proceedings of Member Associations

NEW ENGLAND SEWAGE WORKS ASSOCIATION

1945 Spring Meeting

Boston, Massachusetts, May 2, 1945

The Spring Meeting of the New England Sewage Works Association was held at the Hotel Statler in Boston on Wednesday, May 2, 1945. A total of 110 members and guests attended, most of whom were residents of the metropolitan area of Boston. President Frank L. Flood presided at all sessions.

Upon completion of the Secretary-Treasurer's reports and other pertinent Association business, the following papers were presented at the morning session:

"Porous Tube Air Diffusers" by Frank C. Roe, The Carborundum Company, Perth Amboy, New Jersey.

"Sewage Treatment Operation Charts" by W. Vincent Barry, City Engineer, New Haven, Conn.

"Small Sludge Elutriation Plants" by Albert L. Genter, Consulting Engineer, Baltimore, Md.

Immediately after the luncheon served in the Salle Moderne Room of the Hotel Statler, an address was given by Mr. Charles W. Sherman, previously a partner of Metcalf and Eddy, Consulting Engineers. Mr. Sherman spoke on "The Siege of Boston (1775–76)."

The technical session of the afternoon consisted of a symposium on "Treatment and Disposal of Digestion Tank Supernatant Liquor" with a paper by L. L. Langford, Eastern Sales Manager of the Pacific Flush Tank Company, New York City, and discussions by L. H. Chamberlain, American Well Works, New York City, Anthony J. Fischer, The Dorr Company, New York City, and Joseph Doman, Sanitary Engineer, Greenwich Department of Public Works, Greenwich, Connecticut.

LeRoy W. Van Kleeck, *Secretary*

NEW YORK STATE SEWAGE WORKS ASSOCIATION

Seventeenth Annual Meeting

New York, New York, January 19, 1945

The Seventeenth Annual Meeting of the N.Y.S.S.W.A. was held in New York City on January 19, 1945, with headquarters at the Pennsyl-

vania Hotel. About 250 members and guests were registered. The meeting was very well attended and proved to be one of the best and largest of our annual meetings, in spite of difficult travel conditions and the difficult room situation at hotels.

On January 18 members of the Association were guests of the Sanitary Engineering Division of the American Society of Civil Engineers, which held its meeting in the Hotel Commodore. The technical program included the following papers:

Depletion and Recharge of Ground Water Supplies, by Charles L. McGuinness.

Postwar Planning in the Sanitary Engineering Field, by E. Sherman Chase.

Water Supply at the Battle Front, by Capt. W. H. Smith, U.S.N.

Evaluation of Sewage Works Data, by William L. Havens.

Characteristics and Disposal of Wastes from the Copolymer Synthetic Rubber Industry, by George E. Barnes and M. M. Braidech.

The Future of American Engineers in Latin America, by John P. Hogan.

The executive committee of the N.Y.S.S.W.A. met on the evening of January 18. The meeting was presided over by W. H. Larkin, President of the Association. George E. Symons of New York City and Associate Editor of *Water Works and Sewerage* was elected President for the year 1945 and Uhl T. Mann, Superintendent of the Ley Creek sewage treatment plant at Syracuse, was elected Vice President. Edward J. Smith (Niagara Falls) was elected Director to serve on the Board of Control of the Federation of Sewage Works Associations for a term of three years beginning at the close of the first session of the Board in October, 1945. A. S. Bedell, of the New York State Department of Health, Albany, N. Y., was re-appointed Secretary-Treasurer, as were J. C. Brigham, Assistant Treasurer, and A. W. Eustance, Assistant Secretary, also of the State Department of Health.

James C. Harding (White Plains), Alexander G. Martin (Kenmore), and Benjamin L. Smith (Albany) were elected to the executive committee for a term of three years. Retiring members from the executive committee are W. D. Denise, W. H. Larkin and Edward J. Smith.

With reference to the spring meeting, it was decided that due to the present ban on such meetings by the Federal government, no definite spring meeting would be planned. In lieu of this it was decided to request the Capitol District Section of the Association to plan a meeting in Albany for the second week in June which, if restrictions were lifted, could be turned into a statewide meeting. The services of the program committee and other committees will be given to the Capitol District Section in order that a more extensive program and suitable arrangements could be made in case it becomes possible to hold a statewide meeting. In any case the executive committee will meet in the second week of June in Albany in order to conduct the business of the Association.

At the executive committee meeting, the following resolution was passed and was read at the business meeting by President Larkin:

Be it hereby resolved that the executive committee on behalf of this Association go on record as expressing their appreciation and approbation to W. H. Wisely, Editor of *Sewage Works Journal*, for the manner in which he has undertaken and carried through the development of the operators section of the *Journal*, which has greatly enhanced the value and the services of the *Journal* to sewage treatment plant operators and all others engaged in this field of endeavor.

At the general business meeting on Friday it was noted that the Association now has an active membership of 563 with five local sections whose members total 180. The reports of the activities of these local sections as well as of the various standing committees of the Association were presented and discussed at this meeting.

The first technical paper given at the morning session on January 19 was entitled "Practical Application of Principles of Modified Sewage Aeration," which had been prepared jointly by L. R. Setter, W. T. Carpenter and George C. Winslow, Principal Sanitary Chemist, Senior Chemist and Engineer in Charge, respectively, of the Jamaica sewage treatment plant of the Department of Public Works, New York City. The paper was presented by Dr. Setter and he advised that in the operation of that particular plant they had worked on the idea that it was possible to get any desired degree of treatment from plain settling to activated sludge by the use of this principle of modified sewage aeration. The Jamaica plant was used to check earlier pilot plant studies. In all, four separate systems of treatment were investigated for comparison of the effectiveness of each system. These systems differed in the amount of air used, amount of solids returned and in aeration and settling times. This paper was discussed by Robert Shapiro, who described similar work at the Bowery Bay sewage treatment plant.

At the luncheon meeting held in the Penn Top of the Hotel Pennsylvania, Dr. Albert E. Berry, President of the Federation of Sewage Works Associations, extended the greetings of the Federation and spoke regarding the proposed meeting at Toronto in October, 1945. Dr. Berry then presented to Mr. C. A. Holmquist, Director of the Division of Sanitation, New York State Department of Health, the Kenneth Allen Award certificate of the Federation, which award is given triennially to a member of each of the member associations for outstanding service in the sewage works field as related particularly to the problems and activities of that member association. In accepting the award, Mr. Holmquist stated that he would cherish it most highly because of his personal acquaintance with Kenneth Allen.

The Kenneth Allen Memorial Awards of the New York State Sewage Works Association for the best paper of a scientific or research nature and for the best paper by an operator showing unusual work at his plant were presented by H. H. Wagenhals, Chairman of the Kenneth Allen Memorial Award Committee, who presented token

awards since the bronze plaques will not be obtainable until after the war.

The research award was presented to Dr. Harry W. Gehm, Technical Advisor, National Council for Stream Improvement, of the Pulp, Paper and Paperboard Industries, Inc., New York, N. Y., for two papers published in *Sewage Works Journal* entitled "Neutralization of Acid Waste Waters with an Up-flow Expanded Limestone Bed" and "Volume Characteristics and Disposal of Laundry Wastes."

The operation award was presented to Dr. L. R. Setter and Dr. Gail P. Edwards for their paper entitled "Modified Aeration—Part II."

W. H. Wisely, Executive Secretary and Editor, Federation of Sewage Works Associations, gave a brief talk on Federation activities. He reported that there was nothing definite as yet regarding the Toronto meeting but that it was hoped that permission would be granted to hold this meeting. He stated that a number of the member associations had cancelled their meetings but that he would like to see as many such meetings held as possible because they are the main source of material for *Sewage Works Journal* and requested that contributed articles be submitted to make up for the loss of program papers. Furthermore, it is proposed to intensify the work of the various committees.

Charles A. Emerson of the firm of Havens and Emerson, Consulting Engineers, New York and Cleveland, and past president of the Federation of Sewage Works Associations, gave a most interesting talk on early steps in sewage treatment. He outlined the original methods of sewage treatment and how they had developed and expanded in the past 45 years. He gave much credit to engineers in this country for developing the various methods of sewage treatment and for adapting European methods to our conditions. At the close of his talk he gave a roll call of the men who made national contributions to the art of sewage treatment during the past years. In connection with this, he mentioned the work done in the Lawrence Experiment Station in Massachusetts, and after his talk one of the original chemists at this experimental plant, Dr. W. R. Copeland, briefly addressed the meeting.

The first paper in the afternoon session was one prepared by A. E. Griffin, Assistant Director, and N. S. Chamberlain, Sanitary Chemist, Technical Service Division, Wallace and Tiernan Company, Newark, N. J., on "Exploring the Effect of Heavy Doses of Chlorine on Sewage." In this paper Mr. Griffin outlined the effects of heavy doses of chlorine on the ammonia content of the sewage and compared these phenomena with the effects of heavy doses of chlorine in water.

The second paper in the afternoon session was presented by Willem Rudolfs, Chief, Department of Water and Sewage Research, New Jersey Agricultural Experiment Station, and Louis Fontenelli, Chief Operator of the Rahway Valley sewage treatment plant, on the "Relation Between Loading and Supernatant Liquor in Digestion Tanks." Dr. Rudolfs pointed out that there is a definite relation between loading and supernatant liquor because with excessive loading it is impossible to obtain a satisfactory supernatant overflow. His paper was

based on tests at actual plants as well as on laboratory studies. The next paper was one entitled "Co-ordinated Industrial Waste Research" by Harry W. Gehm, Technical Advisor, National Council for Stream Improvement, of the Pulp, Paper and Paperboard Industries, Inc., New York City. In this paper Dr. Gehm outlined the steps now being taken by the Council and what it hoped to do in the future.

The last formal paper was given by Anthony J. Fischer, Development Department, The Dorr Company, Inc., New York City, and entitled "Plant Scale Tests on Thermophilic Digestion." Dr. Fischer pointed out the differences in sludge and supernatant obtained with high and low digestion temperatures.

Major Andrew J. Fuller, on military leave from the New York State Department of Health, gave a very interesting description of his experiences in Africa, India and China where he has been serving for the last three years. In his brief talk Major Fuller pictured sanitation conditions in that part of the world. He outlined also some of the troubles which his organization experienced in getting proper sewage treatment facilities at army bases established in those areas.

The meeting was adjourned at 5:15 P.M. by President-elect G. E. Symons, who presided at the afternoon session.

A. W. Eustance, *Assistant Secretary*

PENNSYLVANIA SEWAGE WORKS ASSOCIATION

1945 Lecture-Laboratory Course for Sewage Works Operators

St. Joseph's College, Philadelphia, Pa., April 11–May 23, 1945

When it became evident early in 1945 that the usual annual meeting of the Pennsylvania Sewage Works Association could not be held at State College because of travel restrictions, the Executive Committee of the Association immediately laid plans for a training course for sewage works operators that would comply with the requirements of the Office of Defense Transportation. Such a short course was considered particularly justifiable in view of the intense pollution abatement campaign which has been undertaken by the Pennsylvania Sanitary Water Board. Some 200 Pennsylvania municipalities have been requested to provide major sewage works improvements at the end of the war and the Pennsylvania Sewage Works Association has integrated its program with that of the Sanitary Water Board with the aim of providing trained personnel to operate the new and improved works.

At the meeting of the Executive Committee of the Association held at Harrisburg on January 29, the following committee was appointed to arrange for the short course and develop the program: F. S. Friel, Chairman; Gordon J. Wiest, Vice-Chairman; Robert M. Bolenius; Bernard S. Bush; George A. Elias; L. D. Matter and Norman G. Young.

In order to provide for a maximum attendance with a minimum of travel, it was deemed advisable to stage the school in a large city; ac-

cordingly, arrangements were made for the short course to be given at St. Joseph's College in Philadelphia. Futher arrangements were made for the course to be sponsored by the United States Office of Education through the Engineering, Science and Management War Training Program. The State Department of Health and the Sewage Works Operators' Association of Southeastern Pennsylvania collaborated with the Pennsylvania Sewage Works Association in the development of the lecture and laboratory program.

The course was given in a series of one-day sessions on consecutive Wednesdays from April 11 to May 23, 1945, inclusive. Total registration for the course was 65 and proof of the excellence of the program is evidenced by the attendance record of 99.6 per cent, based on total student hours. The first two hours of each session were devoted to lectures on sewage treatment topics by prominent engineers, chemists, and bacteriologists and the remaining 2½ hours were devoted to instruction and demonstrations in the laboratory under the supervision of the faculty and lecturers. The presiding faculty comprised:

The Very Rev. John J. Long, President of St. Joseph's College
Rev. Joseph J. Molloy, Head of the Department of Chemistry, St. Joseph's College
Rev. Martin J. Casey, Assistant Professor of Chemistry, St. Joseph's College
Joseph N. Bartlett, Associate Professor of Chemistry, St. Joseph's College
George A. Elias, District Engineer, Pennsylvania Department of Health, Philadelphia
Harry J. Krum, City Chemist and Bacteriologist, Allentown
Gordon J. Wiest, Chemist and Bacteriologist, Jenkintown.

The lecture portion of the course included the following papers:

Wednesday, April 11

"General Duties of the Operator and the Reasons for Sewage Treatment" by H. E. Moses, Chief Engineer, Pennsylvania Department of Health, Harrisburg.

"Characteristics of Sewage" by Dr. Harry W. Gehm, Jr., National Council for Stream Improvements, New York City.

Wednesday, April 18

"The Theory of Primary and Complete Treatment Including Trends and Progress" by Linn H. Enslow, Vice-President and Editor, *Water Works and Sewerage*.

Wednesday, April 25

"Operation of Screens, Grit Chambers and Sedimentation Units" by W. Allen Darby, The Dorr Company, New York City.

"Operation of Imhoff Tanks" by P. N. Daniels, Trenton, N. J.

Wednesday, May 2

"Operation of Intermittent Sand Filters" by Col. Frank E. Daniels, Chief Chemist, Pennsylvania Department of Health, Harrisburg.

"Operation of Trickling Filters" by Frank Woodbury Jones, Havens and Emerson, Cleveland.

Wednesday, May 9

"Theory of Sludge Digestion—Operation of Separate Sludge Digestion Tanks" by L. L. Langford, Pacific Flush Tank Company.

"Sludge Drying, Sludge Gas Utilization and Plant Hazards" by L. W. Van Kleeck, State Department of Health, Hartford, Conn.

Wednesday, May 16

"Operation of the Activated Sludge Plants" by Gail P. Edwards, Chief of Laboratories, New York City.

"Chlorination of Sewage" by Harry A. Faber, Research Chemist, Chlorine Institute, Inc., New York City.

Evening Session

"Trouble Shooting on Chlorinators" by Harry J. Krum, Chemist and Bacteriologist, Allentown.

"Discussion on Chlorine Handling" by F. W. Nienow, Pennsylvania Salt Manufacturing Company.

"Discussion on Chlorinator Maintenance" by A. M. E. Johnstone, Wallace and Tiernan Company.

Wednesday, May 23

"Sewage Plant Records and Operating Reports" by L. S. Morgan, District Engineer, Pennsylvania Department of Health, Greensburg.

"The Effect of Industrial Waste on Sewage Treatment" by Christian L. Siebert, Executive Engineer, Pennsylvania Department of Health, Harrisburg.

"Operation and Maintenance of Mechanical Equipment" by S. E. Kappe, Chicago Pump Company, Washington, D. C.

At the concluding exercises on May 23, Rev. Joseph J. Molloy presented 64 Certificates of Completion and 9 Letters of Specification to those who attended the course. Addresses were given by George H. Boone, Superintendent of the Norristown sewage works; J. R. Hoffert, Assistant Chief Engineer, Pennsylvania Department of Health; and the Very Reverend John J. Long, President of St. Joseph's College.

B. S. Bush, *Secretary-Treasurer*

Federation Affairs

AN INFORMAL REPORT BY THE SECRETARY

This brief review of current activities of the Federation and its component units is presented in lieu of the verbal report offered by the Secretary at the annual convention. If the reader will seat himself in an armless straight-backed chair and will exercise his imagination to the extent of visualizing the smoke-fogged room; the usual rostrum, occupied by a handful of half-bored officials; the stir and bustle of the audience (part of which is moving casually toward the exits); the wilted and worried chairman, striving to hold his time schedule; the raucous tone of the amplifier—not too well adjusted . . . he may achieve something of the convention atmosphere which he cannot experience in person this year.

1945 Annual Meeting

For the conduct of necessary business in compliance with the Constitution and By-Laws, the Federation Board of Control will hold its annual business sessions at the Hotel Stevens in Chicago on October, 17–18. Chicago was selected by a poll of the Board for its central location and accessibility.

There is expected to be no curtailment of the normal functions of the Board of Control in its 1945 sessions. Committee reports will be received for action and committee direction and guidance will be extended; new officers will be elected; plans will be made for the next annual convention, subject to the lifting of Federal restrictions, and all business pertaining to Federation policies and service will be carried on as usual. There is some concern regarding the attendance by remotely located Directors due to the transportation situation, but every Board member is being urged to represent his constituency in person, if at all possible.

Through the energy and interest of the Publications Committee, headed by Chairman F. W. Gilcreas, it has been possible to salvage the technical program which would have been presented at the 1945 Convention, had it not been postponed. The following series of excellent papers will be published in the *Journal*, beginning with this issue:

The Development of the Activated Sludge Process of Sewage Treatment, by Samuel A. Greeley, Chicago, Ill.

Installation and Maintenance of Sewer Connections, by Nicol MacNicol, Forest Hill, Ontario, Canada.

Trickling Filters—Accomplishments and Future Uses, by E. Sherman Chase, Boston, Mass.

Design of Sewers to Facilitate Flow, by Thomas R. Camp, Boston, Mass.

Conditioning of Supernatant Liquors for Addition to Aeration Tanks, by L. S. Kraus, Peoria, Ill.

Industrial Waste Treatment, by Harry W. Gehm, New York, N. Y.

Treatment and Disposal of Spent Pickling Liquors, by Richard D. Hoak, Pittsburgh, Pa.

Experiences with Activated Sludge at Toronto, by William Storrie, Toronto, Ontario, Canada.

Rising of Activated Sludge in Final Settling Tanks, by Clair N. Sawyer and Leland Bradney, Sioux Falls, S. D.

Operating Experiences at West Middlesex Activated Sludge Plant, by C. B. Townend, Middlesex, England.

Standards of Stream Sanitation, by H. W. Streeter, Cincinnati, Ohio.

Committee Activities

Federation committee functions, in general, appear to have accelerated during the past year. Notable progress in technical and professional services will be reported at the October Board of Control sessions by several important committees.

Sewage Works Practice Committee

While completing one project by virtue of the publication and distribution of Manual of Practice No. 1 entitled "Occupational Hazards in the Operation of Sewage Works," the Sewage Works Practice Committee has added three new proposed manuals to its list. New subcommittees on trickling filters, standard reporting units for sewage works data and on control of public sewer usage have been placed into operation with a view toward production of future manuals of practice concerning those topics. The manual on sludge utilization for fertilizer is in the process of committee clearance and is expected to be the next to be ready for publication and distribution. Progress is continuing on the air diffusion, sewer maintenance and chlorination manuals.

Manual of Practice No. 1 has found a most gratifying demand and has established an enviable record for its successors. More than 6,000 copies have been distributed, to make this project a financial as well as a technical success.

Operators Qualifications Committee

After several years of development, the Committee on Qualifications of Sewage Works Operators will present for the approval of the Board, its final recommendations in regard to classification, certification and training of operators. If and when adopted by the Board, this report will be a valuable guide to agencies sponsoring certification plans in that it will encourage high standards and bring about uniformity in practice across the nation.

Operation Reports Committee

The Committee on Operation Reports has developed the mechanics of a plan by which the Federation would recognize, with an annual award, the outstanding sewage works operation report of each year. The proposal to be presented to the Board of Control involves the establishment of operation report committees in each Member Association, these committees to select the best report from those submitted by indi-

vidual members of each association. The single entry thus chosen from each Member Association would then be submitted to the Federation committee for judgment and final selection of the award winner.

Publications Committee

In addition to the arrangement for the special technical program noted above, the Publications Committee has been giving attention to certain recommended changes in the format of the *Journal*. The proposed changes would modernize and improve the readability of the *Journal* and, if approved by the committee and the Board of Control, would probably be instituted in 1946.

Standard Methods Committee

The Committee on Standard Methods of Sewage Analysis has continued its collaboration with similar committees of A. W. W. A. and A. P. H. A. toward production of the Ninth Edition of *Standard Methods for the Examination of Water and Sewage*. The new edition is in a final stage of editing and is expected to be ready for distribution late in 1945.

Sewage Works Nomenclature

The Committee on Sewage Works Nomenclature is engaged jointly with special committees of A. S. C. E., A. W. W. A., and A. P. H. A. in the production of a "Glossary of Water and Sewage Control Engineering," which will modernize and standardize the nomenclature of these fields. The glossary, when completed and cleared by the participating societies, will be distributed to members of the Federation as a special manual of practice. Good progress is being made at this time.

Miscellaneous Committee Functions

Other special and constitutional committees of the Federation are continuing their expanded functions of recent years.

Those committees concerned with recommendations for honors and awards are proceeding as usual with their duties, although it is likely that the formal presentation of such awards will be deferred until the next Federation convention. The Research Committee, this year under the chairmanship of Dr. Heukelekian, continued its service in reviewing the literature and in surveying the field for current and needed research studies.

Membership

The Montana Sewage Works Association took its place as the 27th Member Association of the Federation as of January 1, 1945. No applications for affiliation by new Member Associations are anticipated this year but interest has been evidenced in such a unit in Louisiana. It is possible that the creation of a Sewage Works Section in the Louisi-

ana Conference on Water Supply and Sewerage may be accomplished by 1946.

The combined Active and Corporate membership of the Member Associations is at a new high, having passed the 3,100 mark early in July. This figure may be compared with the total of 2,855 Active and Corporate Members of record at the same time last year. Membership progress is considered highly satisfactory in consideration of the limitation on Member Association gatherings.

Keen competition is extant as the 1945 membership contests enter their final stage. Twenty of the twenty-seven Member Associations have already equalled or exceeded their membership levels of September 30, 1944, and the remaining associations are all in a position to reach the same goal before the contest closes. The two Member Associations recording the highest numerical and the highest percentage increases will be privileged to name the individuals upon whom the prizes, each a $100 War Bond, will be conferred at the conclusion of the contest on September 30, 1945.

Member Association Activities

Two Member Associations, New York and Texas, were fortunate in having scheduled their 1945 annual meetings prior to the effective date of the O.D.T. ban on conventions; both of these meetings were unusually well attended. The neophyte Montana Sewage Works Association was able to stage its first annual meeting in April for the benefit of a small but enthusiastic registration.

The Canadian Institute on Sewage and Sanitation, not hampered by the overloaded transportation facilities prevailing in the U. S., is proceeding with plans for its regular annual meeting to be held at Windsor, Ontario, in November. As a friendly and hospitable gesture, the neighboring Michigan Sewage Works Association has been invited to participate. This joint function is expected to be one of the highlight events of the year.

Other Member Associations, notably New England, Rocky Mountain and North Carolina, are holding local one-day meetings in large cities so as to avoid violation of the O.D.T. limitation of 50 travelers. A successful gathering of this kind was sponsored by the New England Sewage Works Association at Boston last May, when a technical program of high caliber was presented. The same organization is planning a similar annual fall meeting at Springfield, Mass., in September. The Rocky Mountain Sewage Works Association is also planning a localized one-day meeting in Denver in September and the North Carolina Sewage Works Association will meet likewise at Raleigh, North Carolina, in November. Those associations which are divided into regional sections, such as the N. Y. S. S. W. A., are fortunate in that it has not been necessary to curtail local conferences. The technical program of these meetings have yielded some excellent material for Sewage Works Journal.

The Pennsylvania Sewage Works Association, in lieu of its usual annual gathering at State College, sponsored a comprehensive operator's short course at St. Joseph's College in Philadelphia, with an impressive cast of nationally known lecturers. This event proved to be so successful that it is likely to become a permanent institution.

The need for maintenance of membership contact in the absence of annual meetings has lead to increased emphasis on the newsletters which are periodically distributed by many Member Associations. In two instances, associations which had not previously published such newsletters undertook this worth while activity; *Buckeye Sludge* and *The Windmill*, the new publications of the Ohio Conference on Sewage Treatment and Central States Sewage Works Association, respectively, will take a high place among the bulletins issuing from the Member Associations.

The California Sewage Works Association proposes to publish a 1945 volume of its Journal despite the cancellation of its annual spring and fall meetings. An outstanding series of papers is being assembled for the volume.

The conclusion of the war is certain to bring a closer bond between the British and American units of the Federation but an important move toward this goal was accomplished in 1945 by the arrangement which was completed to make possible the distribution of the *Journal* of the Institute of Sewage Purification to American affiliates of the Federation. While relatively few have taken advantage of the opportunity to obtain the 1944 *Journal* of the Institute, in accordance with the notice published on page 393 of the March, 1945, issue of the *Journal*, it is believed that a substantial number of American workers will take advantage of the exchange agreement in the future. A further tightening of the bond across the Atlantic should result from the Institute's cordial invitation to American Federation affiliates who may be visiting in England, to utilize the services and facilities of the Institute.

All in all, the Federation is enjoying a good year despite the mounting handicaps of wartime operation. The complete cooperation of all officers, Member Association officials, committee personnel and the membership-at-large is gratefully acknowledged.

W. H. Wisely, *Executive Secretary*

Reviews and Abstracts*

Conducted by
GLADYS SWOPE
Mellon Institute of Industrial Research,
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OBSERVATIONS ON THE PROPERTIES AND PURIFICATION OF WASTE WATERS FROM FRUIT AND VEGETABLE CANNERIES

BY D. DICKINSON

Presented before The Institute of Sewage Purification, Midland Branch, February 15, 1945

An introduction describes the situation at English canneries, e.g., seasonable and variable wastes difficult to treat by conventional methods, which generally parallels conditions in America. This investigation is in its early stages and a complete solution cannot be presented but data on compositions and properties are offered as an aid in solving difficulties which may arise from the discharge of cannery wastes into municipal sewers or streams with inadequate dilution.

As fruits give rise to much less waste water because of simpler processing the paper deals with vegetable wastes, particularly those from potatoes which have been canned on a large scale for the first time, as a war-time measure. Wastes from vegetable canning are to be expected from (*a*) prewashing, (*b*) peeling, (*c*) blanching, (*d*) cooling vegetables, (*e*) cooling cans, and (*f*) floor and machinery washing.

Potatoes are washed to remove adherent soil; heated in boiling water, dilute caustic, or boiling brine to loosen skins and eyes; peeled and washed simultaneously in a continuous, abrasive-type peeler from which waste water discharges continuously; and immersed in dilute brine to prevent browning if they are to be stored for a time. Approximately 30 per cent of the weight of raw potatoes, equivalent to about 6 per cent of the potato weight as dry solids, enters the waste water.

Much of the polluting matter can be removed from the waste water by suitable automatic screening although the proportion removed will depend on raw vegetable quality, method of preparation for peeling, and type of peeler. Table I shows the results obtained on an automatic screen in which the wastes flow over a sheet of semi-cylindrical copper pierced with 1/16 inch holes swept by brushes which remove the solid matter. The small scale experiments were made with a replica of the commercial device. The results are not easy to interpret because of the difficulty of maintaining comparable conditions, but it is apparent that a considerable degree of purification is obtained by simple screening. An advantage of screening is the reduction in sludge volume which is not revealed by the reduction of total solids shown in the table. Experiments showed that screened waste from beet peelers contained about 60 per cent less sludge than the unscreened waste. Analogous results were found with other vegetables. Although the necessity for screening has been emphasized, the great value of this simple process is still not generally appreciated.

Screened potato waste contains a proportion of colloidal matter which varies with the canning process, but the true suspended matter settles rapidly without the aid of a precipitant. The sludge volume, which fluctuates widely, is normally about 8 per cent of the total after one hour settlement and shows little tendency to compact. Experiments indicated that the dry solids in the screened waste could be reduced about 60 per

* It will be appreciated if Miss Swope is placed on the mailing lists for all periodicals, bulletins, special reports, etc., which might be suitable for abstracting in this *Journal*. Publications of public health departments, stream pollution control agencies, research organizations and educational institutions are particularly desired.

TABLE I.—*Data on Screening of Cannery Wastes*

Vegetable	Treatment before Peeling	Type of Peeler	Gal. Water per 20 lb. Veg.	Screenings Removed, Lb./Gal.	Dry Solids in Screenings, %	Removal of Total Solids, %	Scale of Experiment
Potatoes	None	Rotary	15	.12	—	14	Small
	4 min. in boiling 5% NaOH	Rotary	2.4	.11	5*	5.5	Small
	5 min. in boiling water	Rotary	2.5	.47	8	7.5	Small
	3 min. in boiling 35% NaCl	Rotary	3.6	.31	11	5.0	Small
	5 min. in boiling NaOH	Roller		.74	8		Small
	None	Rotary		—	24	35	Full
	10 min. in boiling water	Roller			10	24.5	Full
Beets	Scalded	Roller			6	31	Full
	Scalded	Rotary	—	—	12	40	Full
Carrots	None	Rotary	4.5	.13	4	35	Small
	4 min. in boiling water	Rotary	12			14	Small
	3 min. in boiling 3.7% Na_2CO_3	Rotary	7			11	Small
	5 min. in boiling 2% NaOH	Rotary		—	6	31	Full

* Screenings drained with difficulty.

cent by settling for one hour. Changing the position of the influent baffle board had little effect on the sedimentation efficiency but had a marked effect on the shape of the sludge mass. It was concluded that best results would be obtained where the wastes were discharged into a full settling tank with the baffle set about one-third of the distance from the influent end.

A full-scale sedimentation plant was kept under observation since it was first put in operation in January, 1944. It consists of two parallel settlement tanks of conventional rectangular design, preceded by a small detritus tank. Each has a capacity of 10,000 gallons and each is used in turn for settling a flow averaging 25,000 gallons per day. There is provision for the addition of chemicals and the settled effluent is allowed to run in a series of channels containing clinker and limestone chips before final discharge. Samples of the crude waste, settled waste, and final effluent were taken every hour during the working day on four days each week. The composite samples were tested on the spot for suspended solids (cc./liter, settled 16 hours in Imhoff cones), pH, and oxygen consumed from boiling permanganate. Table II summarizes the results.

On observational evidence the addition of lime to potato waste assisted materially in preventing the sludge from rising due to fermentation. No improvement was gained by increasing the quantity of lime from 2.8 to 4.0 pounds per 1,000 gallons, nor by adding nitrochalk, but addition of these chemicals was accompanied by a complete absence of odor from the plant. Addition of sodium aluminate to the waste resulted in good floc formation and clarification when the pH of the mixture was below 5.8. Aluminoferric was without effect.

The value of the clinker-filled channels was questioned but purification based on the oxygen consumed test showed that their use was justified. Purification in the channels is due to biological action, since the suspended matter found in the final effluent consisted largely of microorganisms.

The sludge was partially removed from the settling tanks each day and each tank was emptied completely after a run of about a week. The sludge was treated with lime before being pumped to drying beds. Potatoes produce a large amount of sludge which has proved extremely difficult to handle. Its gelatinous nature does not permit it to drain well. It contains an average of about 8 per cent of dry solids and the maximum drying obtained during a summer dry spell was from 7 to 14 per cent of dry solids in 35 days. Even the dried sludge is therefore difficult to handle. Some attempts at digestion have been made but these had to be abandoned due to the production of high con-

TABLE II.—*Effect of Sedimentation in Continuous-Flow Rectangular Tanks*

Product Canned	Unscreened Waste Treated						Screened Waste Treated		
	Potatoes			Beans in Tomato	Plums and Canned Beans	Runner Beans	Runner Beans	Beets	Beets
Period, Days	19	17	22	53	9	9	9	16	17
No. of Daily Samples	10	11	11	25	8	7	5	11	11
Suspended Matter in cc./liter									
(*a*) Crude Waste, Range	4–159	11–147	11–130	1–34	2–20	1.4–6	1.4–9	12–38	5–39
Crude Waste, Mean	57	50	63	5	8	4	4	24	23
(*b*) Effluent, Range	0.2–60	1.4–47	1.3–54	0.2–2.5	0.3–8	0.4–3.4	0.8–1.4	0.7–2.5	0.7–4.2
Effluent, Mean	17	14	15	1	3	1.1	1.2	1.4	1.7
Mean Removal, %	70	72	76	80	63	72	70	94	93
pH of Fresh Samples of									
(*a*) Crude Waste, Range	6.0–8.4	6.9–8.4	8.4–9.6	5.1–7.3	6.0–7.0	6.6–7.5	7.1–7.3	6.8–8.0	5.7–6.9
Crude Waste, Mean	6.8	7.8	9.3	6.2	6.4	7.0	7.2	7.3	6.1
(*b*) Effluent, Range	5.3–6.9	5.1–6.7	5.1–8.5	5.0–7.7	5.2–6.6	7.1–8.6	6.1–6.9	4.5–6.8	4.6–6.1
Effluent, Mean	6.3	5.8	6.6	6.7	5.7	7.5	6.6	5.2	5.4
Oxygen Consumed (p.p.m.) by									
(*a*) Crude Waste, Range	540–1600	610–1510	450–860	190–790	330–470	110–440	160–450	420–810	680–790
Crude Waste, Mean	1130	950	710	420	410	300	310	680	740
(*b*) Effluent, Range	300–1070	410–1070	290–740	100–620	190–420	100–210	110–210	220–630	300–630
Effluent, Mean	620	680	540	290	320	150	150	460	540*
Mean Purification, %	45	28	24	30	23	50	52	32	34
Chemical Treatment	A	B	C	C	D	C	None	A	B

Chemical treatment: A = 2.8 lb. CaO/1,000 gal.
B = 4.0 lb. CaO/1,000 gal.
C = 4.0 lb. CaO/1,000 gal. + 0.5 lb. nitro chalk
D = 9.0 lb. sodium aluminate/14,000 gal.

Editors' Notice. Nitrochalk is a fertilizer containing 10% of available nitrogen. It consists of ammonium nitrate and calcium carbonate.

centrations of acids by bacterial action. The developed acidity is sufficient to stop further digestion. No difficulty was found in drying the sludges from other vegetable wastes.

Further purification of the settled waste without adequate dilution is likely to prove difficult. A sample of the effluent from the plant during potato canning was kept in an open beaker for four weeks and the rate of oxygen absorption determined at intervals. It was found that the curves of absorption rates departed from the usual logarithmic shape and, excluding the initial lag period, the rate of oxygen absorption remained almost constant for five days. It was concluded, therefore, that purification of this waste in a biological filter or an activated sludge plant would require an unusually long time.

An investigation was made at a rural sewage treatment plant where it was reported that the plant was being overloaded with cannery waste. The plant handles 200,000 gallons of sewage and 40 to 50,000 gallons of cannery waste water per day. The mixture had been treated successfully for many years preceding the complaint and it was found that the trouble was due directly to the greater load imposed by the potato waste. The major effect was on the primary sludge where the available drying time had been reduced by 50 per cent. The sludge did not dry in this time and it was found necessary to remove it from the beds with ladles and spread it in thin layers on the surrounding land. The mixture of potato and sewage sludges appears to be more difficult to dry than potato sludge alone. The mixture does not drain at all and after some time a thin crust forms over the surface, which does not crack, and which effectively prevents further drying.

The effect of potato waste is to double the strength of the sewage. The oxidation of potato cannery waste is prolonged and it was considered that the effect of this waste on the biological filters was to extend the carbon oxidation stage thus leaving the filters insufficient time to complete the oxidation of the nitrogenous matter. The filters showed no signs of ponding.

RICHARD D. HOAK

DISPOSAL OF WASTE WATERS FROM THE PREPARATION OF VEGETABLES FOR DRYING

BY E. E. JONES

Journal of the Society of Chemical Industry, **64** (No. 3), 80–83 (1945)

During the war the Ministry of Food established plants in different parts of Great Britain, each plant capable of handling 40 tons of raw vegetables per day for dehydration. The vegetables dealt with were potatoes, carrots and cabbages, the highest proportion being potatoes. Before the sites were chosen the Water Pollution Research Laboratory was consulted on methods of treatment and disposal. They advised on the selection of sites from which the waste waters could be disposed of with the minimum of risk of pollution and with the least construction of treatment plants. As a result, this new industry does not cause any serious difficulty from pollution of streams or from interference with sewage disposal works.

The processes in the preparation and dehydration of different vegetables producing waste waters are given. The waste waters from the first washing process (pre-washing) are high in volume and contain a high concentration of suspended matter consisting mainly of soil. The B.O.D. of the liquid after sedimentation varies from 10 to 60 p.p.m. The sludge is dense and non-putrefactive.

Waste waters from peelings contain a high concentration of suspended matter and are very polluting in character. B.O.D. ranges from 300 to 2,000 p.p.m. These wastes form a bulky putrefactive sludge upon sedimentation.

The washing of potato strips produces a waste high in suspended solids nearly all of which is starch. It forms a dense gelatinous sludge. The volume and polluting character of this waste water are usually of the same order as those from the peeling process.

Waste waters from blanching processes are by far the most polluting liquids discharged with a B.O.D. of 5,000 to 15,000 p.p.m. The volume is much less than that dis-

charged from the peeling process. In the table below are given the volume and polluting characteristics of the mixed waste waters (including floor and equipment wash waters).

	Potatoes	Carrots
Volume of waste ton of vegetables processed, gal.	6,820	4,000
B.O.D. (5-day) after sedimentation, p.p.m.	330	860
Suspended solids before sedimentation, p.p.m.	1,217	703
Population equivalent from 10 tons of vegetables per day	12,000	18,000

The polluting effect of waste waters derived from cabbage drying is only less than half as much as those derived from an equal weight of potatoes.

At some locations it was necessary to remove the coarse suspended solids before discharging to sewers for further treatment or to rivers and to the sea. Experiments were performed therefore to determine the sedimentation characteristics of the waste waters from pre-washing and from peeling of potatoes and carrots. The rate of sedimentation as measured by suspended solids and B.O.D. of the supernatant of the wash waters from pre-washing was rapid. The suspended matter from waste waters from peeling settled relatively slowly. Sedimentation had little effect on the removal of B.O.D. of the liquid. Waste waters from washing and blanching of potato strips showed the same results upon sedimentation as waste waters from peeling. On the basis of these results it was recommended that waste waters from pre-washing should be treated by sedimentation separately with one hour detention period. Other waste waters should be mixed and settled in separate tanks arranged in parallel with a detention time of two hours.

At one factory, mixed waters including pre-washing water was settled together after passing through a rotary screen with 16 meshes to the inch. The reduction in concentration of suspended solids due to sedimentation amounted to 76 with potato waste waters. Difficulty was encountered in dealing with the sludge which was dense due to the inclusion of pre-wash waters. The sludge did not flow evenly after mixing with water. During warm weather the sludge had a tendency to rise to the surface. Each of the two tanks was kept in operation for about a week at which time the liquid was diverted to the other tank and the sludge removed from the first. It is suggested that Dortmund type tanks with hopper bottoms would be more suitable as the sludge can be removed more frequently.

Experiments were conducted with percolating filters for locations where complete treatment was required. The crude waste waters from different stages of drying were diluted to approximately the strength of domestic sewage and settled before applying it to the filters. The filter was 6 feet deep, filled with $\frac{3}{4}$ to 1-inch gravel. The average rate of application was 82 gal. per cu. yd. per day on the basis of the diluted waste. The average B.O.D. of the liquid applied to the filter was 240 p.p.m. and of the effluent 10 p.p.m.

H. HEUKELEKIAN

CANNERY WASTE DISPOSAL LAGOONS

By L. F. Warrick, T. F. Wisniewski and N. H. Sanborn

National Canners Association *Bulletin*,* No. 29-L, 48 pp. (April, 1945)

A summary of cooperative work conducted by health departments of several states comprising the Upper Mississippi River Basin Sanitation Agreement and the National Canners Association. It is an account of progress in studies made on the disposal of cannery wastes by lagooning. Lagoons for this purpose may be classified as absorption lagoons (irrigation fields) or holding lagoons, further classified as untreated, chemically treated or surface treated lagoons. Proper application of lagoon methods completely eliminates stream pollution. The methods presented supplement the chemical and biolog-

* Washington, D. C.

ical methods described in the National Canners Association *Bulletin*, No. 28–L, "Methods of Treating Cannery Wastes."

Summary

Storage Lagoons.—Treatment of storage lagoons with sodium nitrate has been successfully used in the treatment of pea, corn, beet, lima bean and green bean wastes. With such treatment canning waste disposal is possible without stream pollution or atmospheric pollution beyond about 200 feet from the lagoon site. At $36.00 per ton delivered for sodium nitrate the total cost including labor and interest on investment for the treatment of a strong waste such as pea waste amounts to 0.5 to 0.6 cent per case. The sodium nitrate alone averages about 0.3 cent per case for pea waste and as low as 0.03 cent for green or wax bean wastes.

Untreated lagoons should be located some distance from inhabited areas to reduce the likelihood of complaints of odors. Instances are known where odor complaints were received a half mile distant from the lagoon. Use of lime, sodium hydroxide or creosote compounds proved unsatisfactory. Cost of disposal in untreated lagoons has been found to be 0.2 to 0.3 cent per case.

Surface treatment of lagoons by the use of oil to suppress odor development has proved unsuccessful.

Absorption Lagoons.—Irrigation fields are satisfactory where soil is porous and absorption is rapid. Unabsorbed wastes must not be permitted to reach streams. The cost with this method is about 0.1 cent per case.

Absorption lagoons treated with lime or sodium hydroxide require good absorption. It need not, however, be as rapid as the absorption in irrigation fields. Such lagoons should be located a considerable distance from inhabited areas. With sodium hydroxide such lagoons can be operated at a cost of 0.3 to 0.6 cent per case.

General Considerations

Treatment at a municipal treatment plant may prove satisfactory if the capacity is adequate and arrangements can be made. A complete biological treatment plant at the cannery is not adaptable to seasonal canning operations. Lagoon treatment provides complete treatment at a relatively low cost, though a large area is required. The type of lagoon selected will depend on the nature of the soil and the location with regard to inhabited places. The site of any type of lagoon should be so chosen that no contamination of underground sources of water supply will result.

Screening through a 40-mesh screen is necessary whatever the method of disposal. It is necessary in the case of lagoons as an aid to odor control. To reduce the area of lagoon required, cooling tank water should be discharged separately. Silage or stack juices should not be discharged to lagoons as these strong wastes result in odor troubles.

The following table shows the volumes and analyses for various types of cannery wastes. The volumes of waste do not include cooling water or silage or stack juices.

Type of Waste	Waste per Case, Gallons	B.O.D., p.p.m.	B.O.D., Pounds per Case
Beans, green or wax	26	200	0.043
Beans, lima	50	450	0.156
Beets	25	2,500	0.52
Corn	25	3,000	0.63
Peas	25	2,400	0.50

Results of Studies

Irrigation Fields.—At Hampton, Iowa, unscreened wastes from peas and cream style corn are discharged along with tank water to a field 1.88 acres in area. The furrows are about 24 in. wide at the top and 15 in. wide at the bottom and are 9 in. deep. The ridges

are 36 in. wide. The field has been in use since 1934. During the period of observation, the corn canning season in 1942, there was some odor. It was noticeable only at the edge of or directly in the field. During the 1942 season wastes were discharged at an average rate of 176 gallons per minute during working hours and clean-up time. The cost for the season was $280, which included rental and cost of operation. This amounted to 0.12 cent per case.

At Waverly, Iowa, screened wastes from the packing of cream style corn were mixed with wastes from the silage stack and discharged to a field containing 1.87 acres. The receiving furrows are 42 in. wide at the top, 24 in. wide at the bottom, and 18 in. deep. The ridges are 42 in. wide. The field has been in use since 1935. Observations were made in 1942. Wastes were applied at a rate of 123 gallons per minute during working hours. The cost for the year was $185, including land cost and cost of operation. The cost per case was 0.097 cent. Odors were noticeable only at the field.

Untreated Lagoons.—Four untreated lagoons in Iowa were studied in 1942. Strong offensive odors were produced. The lagoons received corn wastes and silage stack juices. Costs averaged 0.3 cent per case.

During 1943 two untreated lagoons in Illinois received screened pea and corn wastes. The lagoons were located in black loam soil underlaid with gravel and the wastes seeped away rapidly. There were no odor complaints.

Operation of two untreated lagoons in Wisconsin in 1942 produced odor complaints. There was little or no seepage from these lagoons.

Chemically Treated Lagoons.—Use of lime at four lagoons in Wisconsin prevented seepage because of clogging of pores in the soil. Odors resulted from the storage of screened and lime treated pea and beet wastes.

At another Wisconsin cannery screened pea wastes were treated with sodium hydroxide at a rate of 1 to 3 pounds per 1,000 gallons and discharged into a lagoon located in gravel. Absorption was rapid and little odor resulted. This lagoon has been in service since 1932. Two other lagoons located in tight soil received screened and sodium hydroxide treated pea and whole kernel corn wastes. Offensive pig pen odors resulted.

At Medford, Wisconsin, pea wastes are discharged into a lagoon after screening and sodium hydroxide treatment. In 1942 caustic soda in the amount of 11,600 lb. were added to 3.4 million gallons of waste. The pH remained below 7.2 until the last week of the pack, and rose to 8.4 over a period of three weeks after the close of the season. Laboratory tests indicated that 5 lb. per mil. gal. were required to maintain a pH of 7.2, and 11 lb. for a pH of 9. Odors were not decreased by this treatment and natural purification proceeded at a slower rate.

Sodium Nitrate Treated Lagoons.—The function of sodium nitrate is to furnish oxygen for aerobic bacterial decomposition during the early stages of decomposition; to stimulate the growth of chlorophyllaceous organisms which in turn produce additional oxygen by photosynthesis; and to maintain an alkaline reaction. Canning wastes exert an oxygen demand greatly in excess of that which can be supplied by aeration. Hence odors are produced. It appears practical to use quantities sufficient to satisfy 20 per cent of the 5-day B.O.D. in shallow lagoons. By this means the odors produced do not carry beyond 200 feet.

At Hoopestown, Illinois, sodium nitrate was used with whole kernel and cream style corn wastes which had been passed through a 40 mesh screen. The chemical contained 54.7 per cent oxygen by weight and was dissolved in water and discharged into the wastes at a rate of 2.88 lb. per minute. Wastes were pumped at a rate of 300 gal. per minute. The 5-day B.O.D. of the wastes was 3,500 p.p.m. and the sodium nitrate added was sufficient to satisfy 18 per cent of the B.O.D. There were no complaints of odors from the lagoons, located about one fourth mile from the business district.

Sodium nitrate was used at Lake Mills, Wisconsin, with pea wastes having a 5-day B.O.D. of about 1,600 p.p.m. It was estimated that 120 pounds of commercial grade chemical per 1,000 cases would be necessary to satisfy 20 per cent of the B.O.D., though at the end of the season it was calculated that actually only 17.6 per cent was satisfied. In contrast with previous years no complaints were received regarding odors. The cost per case was 0.33 cent on the basis of $55.00 per ton for sodium nitrate.

At Poynette, Wisconsin, pea wastes were screened and then passed through a two compartment chemical precipitation unit in which lime and ferrous sulfate was used. The effluent was treated with 65.1 lb. of sodium nitrate per 1,000 cases packed. When packing corn the chemical was used at an average rate of 112.9 pounds per 1,000 cases. It was decided that the chemical precipitation was not justified in view of the additional expense. The following year its use was discontinued and the nitrate dosage was increased.

Effect of Winter Storage on Lagooned Cannery Waste.—The effect of freezing of lagooned wastes was studied during the winter of 1943–44. At one lagoon pea and corn wastes had been treated with sodium nitrate during the canning season. Only a small part of the liquid was lost by soil absorption. Samples taken in February showed a 5-day B.O.D. of 43 p.p.m. in the liquid portion and 32 p.p.m. in the ice portion. In April the B.O.D. was only 30 p.p.m.

At another lagoon nitrate treated corn wastes were stored over the winter. Most of the treated pea wastes were withdrawn before the start of corn canning. In December the liquid portion showed a B.O.D. of 1,560 p.p.m. and the ice portion showed 280 p.p.m. Following the spring thaw the B.O.D. of the wastes was 164 p.p.m. At a third location untreated wastes had a B.O.D. of over 2,000 p.p.m. in the liquid and 280 p.p.m. in the ice portion. After thawing in the spring the B.O.D. was 358 p.p.m.

Correlation of Chemical and Biological Observations.—It was observed that the oxygen demand of nitrate treated wastes dropped rapidly following the close of the canning season. At one location a reduction of 86 per cent of the B.O.D. was observed in 30 days following the end of the pea season. During the next 35 days the demand was reduced to 45 p.p.m.

High dissolved oxygen values are found after the close of the pack, ranging from 2.9 to 18.8 p.p.m. High concentrations are observed during daylight hours. It appears that a major portion of the nitrate is depleted in a very early stage when the computed amounts added and amounts in the lagoon are compared.

Further observation showed the presence of facultative anaerobic bacteria during the early stages of decomposition. During this period rat-tail maggots and chironomous larvae were present in abundance. Chlorophyllaceous organisms appeared during intermediate stages of purification and were present throughout the period following the close of the pack. In lagoons in which the B.O.D. had dropped below 200 p.p.m. and algae were effective in maintaining dissolved oxygen, cladocera and rotifers appeared.

The factors tending to promote chlorophyllaceous growths and attendant B.O.D. reduction can be summarized as follows:

1. Shallow lagoons which permit a maximum of light penetration and natural aeration.

2. Production of quantities of ammonia nitrogen from both organic decompositions and supplemental nitrates.

3. Production of carbon dioxide through decompositions and its retention as sodium carbonate or bicarbonate coupled with the original carbon dioxide content in the natural waters.

4. Favorable weather and temperature conditions.

Size of Lagoon.—As previously mentioned, clean cooling tank water and silage juices should be taken care of separately in a suitable manner. One large lagoon is preferable to several small units if topographic features permit. The operation of two or more lagoons in series is undesirable. If land area is available the depth should be held to a minimum of three feet and it should not be greater than five feet. The volume should allow for 125 per cent of the seasonal volume of waste produced so that a substantial volume of stabilized wastes may be retained for seeding the following year's wastes.

T. L. Herrick

TANNERY WASTE TREATMENT

By H. T. Reuning

Journal of the American Leather Chemists Association, 38, 292–297 (1943)

The author predicts that in the post-war period we undoubtedly will be faced with a Federal law covering the treatment of industrial waste to eliminate the pollution of streams and rivers at which time this problem will assume new importance.

Stream Pollution

American Leather

SURVEY OF TANNERY

Tannery No.	Type of Leather Manufactured	Kind of Tannage	Design Capacity of Treatment Works, Gals.	Theoretical Detention Period, Hrs.		Number Pounds of Raw Hide Per Day	Volume of Raw Wastes Per Day, Gals.	Gallons Raw Wastes Per Pound Raw Hide Per Day	Total Available Settling Capacity of Treatment Works, Gals.
				At Design Capacity	At Present Operating Schedule				
29	Heavy	Vegetable	450,000	71	105	34,000	300,000	8.8	4,000,000
30	"	"	600,000	31	33	46,000	550,000	12.0	2,300,000
31	"	"	250,000	37	54	25,000	170,000	6.8	1,150,000
32	"	"	300,000	9	13½	28,000	200,000 (Est.)	7.1	340,000
33	"	"	100,000	8	8½	24,000	95,000	4.0	100,000
34	"	"	140,000	80	102	16,000	110,000	6.9	1,400,000
1	"	"	225,000	8	8	35,000	225,000	6.4	225,000
2	"	"	50,000	112	140	7,000	40,000	5.7	700,000
4	"	"	270,000	59	80	30,000	200,000	6.7	2,000,000
6	"	"	250,000	19	26	30,000	185,000	6.2	600,000
8	"	"	300,000	16	19	45,000	250,000	5.6	600,000
24	"	"	300,000	133	266	15,000	150,000	10.0	5,000,000
25	"	"	275,000	4	4	58,500	275,000	4.7	144,000
26	"	Chrome and vegetable	1,500,000	48	50	165,000	1,450,000	8.8	9,000,000
19	"	Vegetable	80,000	25	40	25,000	50,000	2.0	250,000
3	"	"	50,000	64	80	7,000	40,000	5.7	400,000
5	"	"	105,000	17	19	15,000	95,000	6.3	225,000

The tanning industry has expended large sums in private investigation and in collaboration with State agencies in an effort to determine a solution to the problem. This is evident by the number of treatment plants being currently operated by the industry to minimize harmful effects on the receiving streams. The committee felt that a survey of systems in operation would prove useful as a guide for future reference. In 1941, a questionnaire was sent to several tanneries under the auspices of the Tanners' Council. The information obtained from this survey is presented herewith in tabular form. Since individual problems vary, it is impossible to suggest a type of treatment that could be readily applicable in all instances.

Committee

Chemists Association

WASTE TREATMENT PLANTS

Description of Treatment	Type of Sludge Removal	Disposal of Sludge		Plant Efficiency—Red'n. from Raw Wastes in:			Discharge Location of Final Effluent
		Temporary	Permanent	Settleable Solids	Suspended Solids	5 Day Bio. Oxy. Demand	
Plain sedimentation. Basins operated as flowing-through units. Final effluent discharged at uniform rate 24 hours per day.	Mechanical	Lagoons	Fill and fertilizer	None given			Stream
Ditto	Hand (Gravity)	"	Lagoons	" "			"
Ditto	Mechanical	"	Fill	" "			"
Tanks used as fill and draw units. Final effluent discharge rate uncontrolled.	"	Sand beds	Fill and fertilizer	" "			Lake
Combined raw waste storage and mixing unit, followed by flowing-through settling unit with continuous sludge removal. Final effluent discharged over 12 hours.	"	Lagoons	Fertilizer	" "			Stream
Ditto No. 29	"	"	Fill	" "			"
Ditto No. 29	"	Sand beds	Fill and fertilizer	92%			"
Basins operated as flowing-through units. Final effluent discharged at variable rate over 10-12 hours.	Hand	None	"	99%–100%			"
Basins operated as flowing-through units. Final effluent discharged normally at variable rate over 24 hours.	"	"	"	90%–95%			"
Two basins operated as fill and draw units. Final effluent discharged at uniform rate over 24 hrs.	"	Lagoons	Lagoons	93%–95%	93%	87%	"
Collection and mechanical flocculation followed by flowing-through settling unit with continuous sludge removal and secondary sedimentation and flow-equalization. Final effluent discharged at uniform rate over 24 hours.	Mechanical	Centrifugal	Fill and fertilizer	95%–98%	85%	80%	"
Two basins operated as fill and draw units. Effluent discharged to combined sedimentation and flow-equalization basin.	Hand	None	Fertilizer	None given			"
Two basins operated as fill and draw units.	"	"	"	" "			"
Basins operated as flowing-through units.	"	Lagoons	Fill	" "	97%	50%	"
Preliminary screening followed by single mechanically cleaned flowing-through unit. Final effluent discharge rate not controlled.	Mechanical	"	Lagoons	" "			"
Flowing-through settling unit for beam house wastes with controlled discharge of final effluent over 24 hours. Yard and scrub house wastes lagooned and discharged at controlled rates during high water periods.	Hand	None	Fill and fertilizer	100%			"
Tanks operated as fill and draw units. Controlled discharge of final effluent over 24 hrs. Spent tan liquors lagooned and released during high water.	Semi-hand	Lagoons	"	95%–98%	94%	88%	"

Stream Pollution

American Leather

SURVEY OF TANNERY

Tannery No.	Type of Leather Manufactured	Kind of Tannage	Design Capacity of Treatment Works, Gals.	Theoretical Detention Period, Hrs.		Number Pounds of Raw Hide Per Day	Volume of Raw Wastes Per Day, Gals.	Gallons Raw Wastes Per Pound Raw Hide Per Day	Total Available Settling Capacity of Treatment Works, Gals.
				At Design Capacity	At Present Operating Schedule				
7	Heavy	Vegetable	255,000	13	15	35,000	225,000	6.4	425,000
22	"	"	2,500,000	10	12	200,000	2,000,000	10.0	3,000,000
13	"	"	Not given			12,000	60,000	5.0	Not given
35	"	"	200,000	22	22½	25,000	195,000	7.8	550,000
	AVERAGE		410,000	39	55	66,857	326,910	6.8	1,620,450
21	Light and heavy	Chrome and vegetable	Not given			45,000	405,000 (Est.)	9.0	Not given
9	Light	"	50,000	16	20	5,000	40,000	8.0	100,000
10	"	"	90,000	14	20	6,000	65,000	10.8	162,000
12	"	"	Not given			Not given	Not given		Not given
15	"	"	2,000,000	4⅓	2½	85,000	1,100,000	12.9	340,000
16	"	"	Not given			Not given	1,000,000		Not given
28	"	"	65,000	10½	13½	5,000	50,000	10.0	85,000
17	"	Chrome	180,000	20	30	10,000	120,000 (Est.)	12.0 (Est.)	450,000
20	"	"	550,000	9	9	45,000	550,000	12.2	600,000
27	"	"	500,000	2	4½	12,000	250,000	20.8	135,000
	AVERAGE		490,714	10	14	26,625	397,778	12.0	267,429
23	Heavy	Chrome	65,000	7½	7½	3,200	65,000	20.3	60,000

In the design of a new treatment works consideration should be given to several factors that have an important bearing on the cost of construction and operation. The capacity of the treatment plant and the cost of operation are controlled by the volume of waste to be handled and, since an ample supply of water is indispensable in the manufacture of leather, it can readily be foreseen that a reduction in water consumption is of importance. Certain wastes have a pollution load so nominal that they can be excluded from the waste to be treated, thus reducing the volume. The use of commercially

Committee

Chemists Association

WASTE TREATMENT PLANTS

Description of Treatment	Type of Sludge Removal	Disposal of Sludge		Plant Efficiency—Red'n. from Raw Wastes in:			Discharge Location of Final Effluent
		Temporary	Permanent	Settleable Solids	Suspended Solids	5 Day Biol. Oxy. Demand	
Mechanical flocculation; primary and secondary sedimentation with flow-equalization to provide uniform 24 hr. discharge. Spent tan liquors lagooned and released during high stream flows.	Mechanical	Lagoons	Lagoons	90%; 95%	90%	81%	Stream
Screening; primary and secondary sedimentation and flow-equalization. Impounding reservoir for low water storage. Spent tan liquors lagooned and released at controlled rates during high stream stages.	"	"	Fertilizer	98%; 99%	94%	50%	"
No description given.	"	"	Lagoons	97%; 98%			"
Basins operated as flowing-through units. Discharge of final effluent regulated uniformly over 16–20 hr. period.	Hand	None	Fill	None given			"
				96%	92%	73%	
Preliminary screening; coagulation with lime; flowing-through grit-chamber. Final effluent discharged to sewer for further treatment in city plant.	Mechanical	None	Fertilizer	None given			City sewer
Two tanks providing alternate fill and draw operation. Uniform discharge of final effluent over 24 hr. period.	"	Drying beds	Fill and fertilizer	93%	89%	89%	Stream
Basins operated as flowing-through units. Final effluent discharged at uncontrolled rate over 10–12 hrs.	Hand	Lagoons	Fill	None given			"
No description given.	Not given	"	Not given	" "			City sewer
Preliminary screening, followed by two mechanically cleaned settling units operated in parallel. Final effluent discharged at approximate rate influent received. Tan liquors decolorized by lagoon leaching; resulting liquid included with raw wastes.	Mechanical	None	Fill	" "	85%	50%	Lake.
No description given.	"	Lagoons	Fertilizer	" "			City sewer
Primary settling tank and two secondary settling basins operated singly or in parallel. Effluent applied to cinder and stone filter beds before discharge. Sludge dried on similar type beds.	Hand	Cinder beds	Fill	" "			Stream
Single flowing-through settling basin. Final effluent discharged at variable rate controlled by influent flow.	Not given	Lagoons	Fertilizer	" "			"
Single flowing-through settling unit.	" "	Sand drying beds	"	" "			"
Single flowing-through settling unit. Sludge removed monthly and dried on cinder beds.	Mechanical	Cinder beds	Lagoon and fertilizer	" "			City sewer
				93%	87%	70%	
Four tanks operated as two parallel flowing-through units. Final effluent discharged over 10–12 hr. period.	Mechanical	Lagoons	Fertilizer	None given			Stream

built, mechanically cleaned screens that separate the heavier solids, such as hair, rope, etc., have been proven very effective for preventing the accumulation of solids that could cause failure of the pumps.

In designing a system for waste treatment it is important to estimate the total volume of waste to be treated in order to gain the greatest efficiency from the settling units, pumps, and other items. The availability of land, the degree of treatment required and the size and type of the receiving stream will also influence the design of the plant. The

type selected, however, should be the simplest compatible with modern engineering principles.

The author concludes his article with the statement that unless experienced employees are in charge of the handling of the system an excellently designed and equipped plant fails to deliver the expected results because of lack of proper control.

JOHN W. HARNLY

WASTES FROM THE ORGANIC-CHEMICAL INDUSTRY AND THEIR UTILIZATION

BY EMIL J. FISHER

Photo-Lithoprint Reproduction, Edwards Brothers, Inc., Ann Arbor, Michigan, 255 pages. Price $5.75.

This book printed in Germany in 1939 is a revision and extension of a similar book published in 1936 and deals with the technical development of industrial waste recovery and utilization. Divided into 27 chapters it presents brief descriptions of manufacturing, waste products, analyses of wastes, characteristics of wastes and methods of recovery. In addition to literature citations a large number of patents are listed. The production of wastes and the possibilities of by-product recovery are sketched systematically, emphasizing the methods proved to be feasible. No attempt is made to discuss the treatment of industrial wastes for final disposal. The industrial processes discussed indicate what is covered in the book: Dry distillation of coal and fuel; production of fats, oils and waxes; resins, camphor, rubber; carbohydrates, paper, cellulose, starches and sugars; textile; breweries and fermentation; milk and food; leather, glue, carbon; organic chemicals; dyes and mixed chemicals. The book is primarily intended for industrial chemists and engineers, but contains considerable information of value in the sanitary field.

WILLEM RUDOLFS

WASTES FROM STEEL PICKLING PLANTS AND THEIR UTILIZATION

BY K. H. TANZLER

Ges. Ing., 66 (9/10) 81–86 (1943)

On the basis of experience obtained in various industries using different methods of treatment and recovery of by-products, it appears that for economical recovery of spent acids and iron salts processes must be installed at the factories concerned. Treatment of mixtures of different wastes or together with domestic sewage is difficult and economically unsound. In addition to reduction of wastes and decrease in volume of washwater by modification of manufacturing processes, the methods of treatment discussed are: filtration or seepage through soil which is simple but rarely feasible, neutralization with lime slurry, neutralization and precipitation of ferro-sulfate with lead salts, neutralization with ammonia and recovery of ammonium salts and red iron oxide, precipitation and concentration of iron salts by vacuum cooling, electrolytic precipitation, and evaporation under vacuum.

WILLEM RUDOLFS

THE BALANCING OF STRENGTH OF SEWAGE DURING SEDIMENTATION

BY S. H. JENKINS, C. H. HEWITT, AND F. W. ROBERTS
Institute of Sewage Purification * (Great Britain)

In this paper sedimentation is considered as an important preliminary process which not only reduces the total amount of impurity in sewage but also tends to minimize flue-

* Preprint of Paper Presented on March 27, 1945, at Birmingham.

tuations in sewage composition. The design of sedimentation tanks which has developed largely upon empirical lines should be improved by the application of theoretical considerations as well.

The work reported in this paper which is preliminary in nature gives observations made at the Saltley Works where most of the sewage from Birmingham and the adjacent drainage district receives sedimentation. It is felt that information already obtained will be useful in post-war improvements at the Works.

The questions being explored in the research program which cannot be definitely answered yet are:

"1. To what extent is the strength of sewage balanced during sedimentation in primary and secondary tanks?
2. How is the efficiency of sedimentation affected by variations in the strength and flow of sewage?
3. Is balancing of the flow in secondary sedimentation tanks accompanied by additional balancing in strength?
4. Does flocculation of suspended solid matter occur during sedimentation? By flocculation is meant the deposition of solid matter which fails to settle out under the influence of gravity within the period normally used in sedimentation tanks."

The first question is the main concern of this paper.

The Saltley Works receives the sewage from about 870,000 persons including the trade wastes from a variety of industries. The primary sedimentation tanks are five in number, whose dimensions range in width from 90 to 100 feet, in length from 302 to 339 feet and in depth to 7 feet at the inlet and to 3½ feet at the outlet end. The capacity in gallons (Imp.) ranges from 1,100,000 to 1,300,000. A diagram showing the plan of the sedimentation tanks at the Saltley Works is given. Each of these sedimentation tanks is cleaned manually about every thirteen days, while the secondary sedimentation tanks are cleaned about every twenty-four days.

Experiment 1 was carried out during thirty-one continuous hours during a period of dry weather. Hourly samples of the sewage, primary sedimentation tank effluent and secondary tank effluent were examined for suspended solids, oxygen absorbed and biochemical oxygen demand. Even though some gas liquor waste was admitted to the primary tank effluent, little effect was observed. The results show definitely that the primary and secondary settling tank effluents followed the characteristics of the raw sewage, but to a diminished degree.

Experiment 2 consisted of a similar run over twenty-four hours and during a period of wet weather, but not too wet to mask the variations in sewage strength. The same variation was noted except that peaks and troughs were much less pronounced than in Experiment 1.

Experiment 3 also included a twenty-four hour run with the "artificial" variation of sewage strength by the admission of gas liquor to the incoming sewage. Again the primary sedimentation effluent showed reduced fluctuation as compared with the raw strength.

Experiment 4 was devoted to the same phenomenon as exhibited in the secondary sedimentation process. Less fluctuation in composition was found, but a definite tendency for the effluent to follow the strength of the influent up or down was noted. It was observed that the period of maximum flow was usually that of maximum strength of the effluent.

Experiments 5 and 6 involve the sampling of the preliminary sedimentation tanks at points that were convenient at the Saltley Works. When this procedure required sampling at points where a layer of scum existed, depth sampling technique was employed. When the tanks were heavy with sludge, samples indicated that some was being scoured from the tank bottom with a consequent deterioration of the plant effluent.

Experiment 7 was concerned with the variation in composition of sewage and tank effluent over a period of one hour. To demonstrate this a clean sedimentation tank is used and samples collected at three minute intervals. As the experiment was conducted during wet weather, the variations found by this sampling technique proved to be larger than those anticipated. This led the authors to the conclusion that "the accuracy as-

signable to a chance sample taken every hour as an indication of the composition of the sewage during that hour may not be of a high order, and raises questions of sampling errors which will be followed up before extensions of this work are attempted."

In conclusion the authors stress the preliminary and exploratory nature of the investigations reported and discuss the analytical methods used. In the tests, samples were compared on a detention period delay basis.

It is further pointed out that while a sedimentation tank is primarily used to remove suspended solids, its action in mixing and so balancing sewage strengths is a very useful one. It is also observed that the mixing effect does not necessarily deteriorate the effluent quality.

RALPH FUHRMAN

THE ENGINEERING PROBLEM OF BALANCING RATE OF FLOW AND STRENGTH OF SEWAGE

By L. B. Escritt

Institute of Sewage Purification* (Great Britain)

"The more that I have had to do with sewage works design the more it has been impressed on me that the best way in which the designer can achieve high class results is to study the requirements of the operator and to make the works not only low in capital costs and sound in construction, but to be sure that their running costs will also be low and that they will be free from operation headaches."

Two items are discussed; first, balancing of sewage flow irrespective of its solids content and, second, balancing the variation in strength. These are particularly significant in plants employing oxidation processes.

For the purpose of this paper the balancing of rate of sewage flow is divided under four heads:

"1. Balancing the effects of storm and wet weather flow.
2. Balancing the periodic discharge from pumping stations.
3. Balancing the effects of trade wastes.
4. Balancing the irregularities of flow that normally occur throughout the average dry weather day."

The paper deals primarily with that listed as number 4, balancing the irregularities throughout the average dry weather day.

To be adequate a sewage treatment works should be able to cope with the variations in strength and flow within their normal variation without upsetting the effectiveness of treatment. The separation of storm water may be accomplished by separating weirs or, less common, by mechanical and electrical devices or overcharging syphons.

Storm tanks are provided for the purpose of temporarily storing a moderate excess of flow above the ordinary maximum to allow return of this excess to the flow of sewage when convenient. This operation may require pumping of the storm tank contents. It usually does require the removal of sludge from these tanks when they are emptied. Sometimes mechanical sweeping is employed to eliminate the manual labor of cleaning. When the storm tanks become filled and overflow they act as sedimentation tanks giving in this way "partial" treatment before overflow into the receiving stream. The storm tanks are usually constructed with a capacity of six hours dry weather flow. While this basis may be questioned, none better has been suggested.

Storm tanks are benefited by improved detail of inlet design. It is further suggested that storm tanks, if properly placed and dimensioned, may take advantage of mechanical sludge scrapers as the Meider scraper for tank cleaning. Their design should also include control for flow diversion to one tank at a time if desirable.

Omission of storm water tanks is not uncommon in moderate sized sewage works.

* A Preprint Presented before the Midland Branch, Birmingham, March 27, 1945.

When they are omitted usually provision is made to by-pass secondary treatment units. Their omission is considered permissible only at works treating sewage from separate systems and when there is some secondary treatment for storm water.

The balancing of pumping flow is desirable to prevent the overloading of sedimentation tanks, dosing syphons, filter arms and other devices. A balancing tank may be employed for this use and connected with the suction well of the pumping station through a floating arm or weir so that the rate of withdrawal is that which the works will handle. Provision must be made for sludge removal at regular intervals in such tanks. Hopper bottoms or mechanical removal devices may be employed. The use of an orifice or syphon has been suggested to avoid the complicated floating weirs or arms.

Balancing may also be used to lessen the effect of variations in strength, temperature, and other characteristics of trade wastes. The application is similar to that of balancing pumping flow.

The balancing out of peak daily rates of flow has been attempted by the author in a particular case, but found to be quite difficult in application. The installation of a balancing tank before the sedimentation tank would aid in that operation because of the lessening of turbulence associated with peak rates of flow. It was found, however, that such balancing did not overcome the flow of organic matter to secondary treatment processes and, therefore, was not fully effective and possibly detrimental. The balancing of load for secondary treatment is dependent upon the degree of mixing which takes place in the preliminary sedimentation tanks. Generally the more mixing given the sewage by a sedimentation tank the less effective it is regarded.

Sedimentation tanks being "hydraulic machines" must be designed to work efficiently at maximum rates of flow. Such design would largely eliminate the need or desirability of balancing.

The effect of balancing the rate of flow and strength on percolating filters is not fully determined. While such filters have a reputation for accommodating heavy loads temporarily, they seem to be helped by variations in strength over longer periods of time. The use of dosing tanks is an example of extreme flow variation and is preferred by some to constant flow. These matters seem to be determined best at an individual plant by tests. Under the usual conditions percolating filters receive the greatest organic load in the afternoon, which is usually the optimum time for bacterial activity. In such a case balancing would be of undetermined value.

In the activated sludge process balancing of rate of flow and strength would be of greater value, though the process itself has a balancing effect. No balancing arrangements are considered desirable for land treatment of sewage.

Experimental work which would measure the effect and value of balancing is necessarily elaborate in nature. In the case of an aeration plant the following requirements are listed to avoid the dangers inherent to such investigations.

"1. Two identical aeration plants shall be worked on the same sewage, one with a balancing arrangement and the other without.
2. The plants shall be arranged so that the balanced flow may be passed to either one or the other, experimental plant changing place with 'control' from time to time.
3. The rate of flow to each plant shall be recorded continually by automatic recorder.
4. 'Round the clock' samples shall be taken of the tank effluent or crude sewage delivered to each plant.
5. Representative samples of final effluent shall be taken from each plant."

By following these precautions proper experiments would show:

"1. Balancing of rate of flow was actually occurring.
2. Balancing of strength was actually occurring.
3. Rate of flow of organics was more even in the experimental plant than in the 'control.'
4. The combined effects of the balancing of strength and rate of flow were producing an improved effluent, or the reverse."

When balancing is combined with sedimentation space additional consideration is necessary to tank design. An efficient sedimentation tank requires (1) a suitable inlet arrangement, (2) an outlet weir which is as far as possible an even distance from the inlet and which collects a thin film of liquid from the surface, (3) a tank of such proportions that vertical currents will not oppose settling, (4) disturbance should be minimized to gain as nearly quiescent settling as possible and (5) tank design should be such that dead tank areas such as horizontal or vertical eddies are eliminated.

If balancing is combined with sedimentation the conflict between the two arises in (1) the difficulty of inlet design to give consistent results with varying level, (2) the outlet weir of proper length drawing from the surface cannot rise and fall to meet the water level variation, (3) a sedimentation tank with varying depth cannot be as efficient as one using the total capacity at all times, (4) comparison should be made with a quiescent sedimentation tank filling and drawing all the time and (5) balancing is not necessarily an effective means of controlling discharges of organic matter unless accompanied by adequate mixing which interferes with efficient sedimentation.

Balancing is required in small works much more often than by large works. Large works serving large areas tend toward a more nearly balanced flow. The balancing tank requires some mechanical devices to give a truly consistent rate of discharge at all heads in the tank. It often aids in sedimentation of detritus as well as some organic matter. To eliminate the difficulty of the floating arm or floating weir a simple module consisting of a controlling orifice and a float operated gate maintains a consistent head on the orifice. Such a module is easy to design for regulating the flow of clean water, but special design is required for the control of crude sewage. A cross section of a balancing tank incorporating a module mixing device and storm overflow weirs is given.

RALPH FUHRMAN

ANIMAL LIFE IN SEWAGE PURIFICATION PROCESSES

BY LL. LLOYD

Presented to a meeting of the Northeastern Branch of the Institute of Sewage Purification,* April, 1945, 20 pages

This is a comprehensive and critical review of the information available on the role, incidence, ecology, types and species of animal life in sewage purification processes with particular emphasis on trickling filters and the activated sludge process. The author states that while these studies may appear to be in the realm of theory, they have a practical bearing on the behavior of the filters.

The animals found in the filters occur also widely in nature under favorable conditions such as mud flats. The most unpleasant of the filter flies *Anisopus cinctus* breeds also on decaying vegetables, rot holes of trees and house sinks. Of the sixteen Psychodas found in the Leeds district three are found in the filters as well as in house sinks. All the others are found in manure piles or decaying vegetables. One reason for the prevalence of the three Psychodas found in filters is the constant wetness. *P. severini* the female breeds without the male, while *P. alternata* and *P. cinerea* must mate, which can take place in the crevices of filters. The rest of the sixteen Psychodas cannot mate in the crevices of filters. This capacity for confined breeding allows the filter species to persist in winter without coming into the open. The Chironomids must come into the open to mate, but they are stronger on the wing than the Psychodas. In localities within a mile of the filter natural breeding grounds are likely to be more heavily infested than similar places beyond one mile range, because of the warmth of the filter the flies can emerge several weeks earlier and disperse.

Protozoa next to bacteria are the most abundant organisms in sewage treatment processes. They manifest a varied manner of life. They may be found in salt and fresh water, live saprophytically and parasitically, aerobically and anaerobically with

* A Preprint.

or without light, etc. Of the motile forms, some swim freely but in sewage processes most keep in close proximity to the organic masses because of the abundance of food. The author attributes a rôle to the movement of the flagella and cilia in addition to bringing food, reaerating and renewing the oxygen supply, especially in drops and films. In sedimentation tanks a few anaerobic pollutional forms are found but because of the short detention time these do not multiply greatly. In sludge digestion tanks, however, they multiply extensively but it has been suggested that even here they do not play an important rôle. In the filters, however, conditions are favorable for their extensive development. Food is abundant. Out of the great many species found the most significant forms are *Opercularia*, *Carchesium*, *Vorticella*, and *Epistylis*, and *Chilodon*. The importance of these forms is due to their size and abundance. Numbers as high as 200,000 per ml. of wet film have been reported. It has also been reported that *Chilodon* on one occasion when it was abundant could cover 1/18 of the surface of the film at any moment.

In activated sludge protozoa have been used as indicator organisms of the condition of the sludge. In comparison with the filter, protozoa are much restricted in variety in activated sludge because in the latter, the environment is rendered more uniform by virtue of mixing and aeration. The more specialized the environment the sparser the variety of animal species. The numbers of *Vorticella* has been reported to be related to the quality of the effluent from an activated sludge plant. As to the rôle they play in activated sludge some claim that they are not important except possibly to aid in the production of more clarified effluents, while others claim that pure cultures of protozoa are as efficient as whole activated sludge and hence aerobic purification of sewage is essentially due to protozoan activity, bacteria playing only a secondary part. The author suggests that protozoa though they may not be dominant over bacteria, must play an important function in activated sludge as well as in the filter. They also secrete a substance which flocculates bacteria and aids in clarification. On prolonged aeration without the addition of sewage activated sludge breaks up and the numbers of protozoa diminish indicating that ciliates take an active part in the removal of organic matter from solution and do not live chiefly by ingestion of bacteria.

Nematode worms are sometimes exceedingly abundant in the filter film and it has been reported that they must stabilize a considerable amount of organic matter and therefore must be beneficial. Their wriggling action may prevent too close matting of the film keeping it porous, well aerated and in closer contact with sewage but not necessarily loosening the film sufficiently to cause sloughing. Of the *Oligochaeta*, *Lumbricus rubillus* is the most abundant. The smaller members of the order occur in vast numbers. The most abundant of these worms is the pinkish *Lumbricillus lineatus* which has the habit of clustering in balls just below the surface stones. *Enchytraeus albidus* is similar but white and is the weaker of the two. The worms of this species lack gripping power and probably a rough porous medium and the presence of solids is to its advantage. The other members of this group are *Limnodrilus* and *Tubifex*. The worms are of great importance in the economy of the filter. It has been reported that *L. lineatus* with no other grazer present, kept the filter open. It worked on the heavy growth of *Phormidium*, rotting its firm attachment and causing it to wash down. The large earth worms are of great importance in loosening the aggregations of humus in the depths of the filters and in the channels below them, thus preventing bottom clogging. The limiting factors to fly variety, giving rise to full range of flies in some plants while in others it is limited to Psychodas, are discussed. In this respect, the strength of sewage is an all important factor. In plants such as in Leeds where the sewage is of medium strength, full range of flies is found, while Huddersfield with strong chemical sewage gives rise to only three species of Psychoda. Of the Psychodas, *P. alternata* is most resistant to extreme conditions, *P. cinerea* next, with *P. severini* the least resistant. During the war, at Huddersfield, the sewage has become so strong that the grazing organisms have become deficient and the filters are ponding. When activated sludge effluent was returned to the filters at this plant reducing the strength of sewage a number of other insects appeared which had not been observed before. At Barnsley where the sewage is similar to that of Leeds, the filters produce the Psychodas and *S. minima*,

but not *Metriocnemus*. This was attributed to the fact that at the former plant the filters are rested. This is adverse to *Metriocnemus* which requires wetted surfaces.

P. alternata has two seasonal peaks, the first in early summer and the second in the fall with a depression in summer. This depression is attributed to shortage of food after the spring slough. Competition from other flies complicates the situation further. Each species of Psychoda has its own season of special prevalence. *P. alternata* has its climax in June; *P. severni* is slightly earlier in May; *S. minima* has its maximum in late summer or early autumn; *M. longitarsus* in midwinter and again in May; *M. hirticollis* is slightly earlier than *M. longitarsus* in winter and slightly later in summer. Thus, there is a procession of prevalent species through the year. The order of this procession is governed by the different responses of the flies to the temperature. *M. longitarsus* and *P. severini* have very low temperature thresholds just above freezing point. When a fly exists almost alone in the filter the governing factors of its incidence are temperature and food supply. When two or more flies are abundant they modify one another's pattern because one has some seasonal advantage over the other in competing for the food. When a carnivorous type such as Chironomid fly is present the patterns are still more modified. The rise and fall of a fly population does not proceed in a steady fashion but does so by a series of alternating peaks and depressions. The peak may be spoken of as "flights" though even in the depressions the insects are flighting in reduced numbers. Any one flight represents not the offspring of the flight immediately precedent but the flight before that. It has been shown that the early flights of *P. alternata* are not the direct product of autumn flights but the grandchildren of these. In winter the offspring of peak emergencies do not show at the surface of the filters. Unlike Chironomids the Psychodas can continue cycle to cycle without showing outside. Increased discharges of filter solids were timed with the unseen peaks of the fly. There is throughout the year a correlation between the solids in the filter effluent and the flights of fly. The author suggests that this correlation is not due to the feeding of Psychodas larvae but to the emergence of the pupae embedded in the solids. Fragile pupae skins left behind leave the solids rotted and cause the collapse of the film which is washed away.

The competition between various species of insects among themselves and with the worms is complex. Between *P. severini* and *P. alternata* the competition is mainly for food since they have no carnivorous tendencies. *S. minima* with its carnivorous habit is dominant over both these after July when its incidence becomes high. *M. longitarsus* has a carnivorous larva and is the most powerful of the group. The larvae of this species dominate the topmost layer devouring the eggs, larvae and pupae of their rivals. It has a low temperature threshold thriving in winter and spring. Its weak point is that larvae and pupae which are just below the surface are killed by the sun when the distributor stops even for a short time. *M. hirticollis* is similar in habits to *M. longitarsus* except that the larvae have higher thermal requirements. Where the worm *Lumbricullus lineatus* is abundant, it is a serious competitor for food against the larvae. The dense population of worms compete more intensely with the larvae during a mild winter than in a cold one. When *Lumbricullus* is present along with a complete fauna, film regulation in a mild winter is a continuous process in the upper layers resulting in an early slough.

In addition, there is competition within the species. This is a phenomenon of summer and autumn when the flies have a tendency to breed beyond the capacity of the filter to support them. An example of this is the summer collapse of *P. alternata* where the fly is breeding with few competitors. The size of the fly is inversely related to the temperature during the later larval growth. For a given temperature a certain wing length can be assigned when the insects are living under favorable conditions. Under conditions of crowding however the flies are smaller than expected because of shortage of food. In other words, the larvae become so abundant in the filters at times that they suffer from food shortage.

The flies reported as causing nuisance are: (1) the Psychodas especially *P. alternata*, (2) *Anisopus cinctus* which is not as abundant or common, (3) *Spaniotoma perenius*. The author believes that the Psychodas are a potential but not a real health hazard. As the range of the fly is a mile, dwellings should not be nearer than this. A

certain amount of fly trouble is probably inseparable from the low rate filter. As regards the high rate filters accounts vary. The flies are present but high rate of dosing prevents their escape from the filter. If the distributor stops they soon make an appearance. Where the macrofauna is diverse there is no serious fly trouble because the Psychodas come under the control of Chironomids; the latter do not cause much nuisance. Some measure of control of Psychodas might be achieved by encouraging the growth of *Metriocnemus*. A surface medium of 2–3 inches grade, a rate of application of one m.g.a.d. is favorable for their growth. Mechanical methods of control are: (1) enclosed filters, (2) flooding. Chemical method of control are: (1) chlorine, (2) creosote.

An attempt is made to balance the advantages and disadvantages of the macrofauna. In the case of activated sludge no benefit is derived from insect larvae and worms, since the amount of solids is under the control of the operator. Invasion of activated sludge by Chironomid larvae is indeed disastrous. In the filter natural clearance of the solids takes place usually in the spring and fall sloughs. English observers believe that the control of growth is entirely an outcome of the grazing of larvae and worms. If these organisms are excluded the beds choke readily. Even in high rate filters the fauna probably plays a part in keeping the growths down since they also contain an active fauna. Do the grazing organisms ever become so active as to destroy a large proportion of the film and reduce the efficiency of the filter? The author suggests that such is not the case since the thickness of the film is not important for purification. Even when there is no visible film, purification is satisfactory. The performance of low rate filters shows little correlation with temperature. Results reported, show that April to June give the worst results while September and October give the best. This might be due to the excessive destruction of the film by the grazing organisms during April to June. Two factors are working against each other; the grazers depleting the film and the temperature compensating for the depletion by allowing a reduced film to do more work. In other words a film that is adequate in summer might prove far from sufficient in winter. The complete filter fauna of worms, Chironomids and Psychodas is advantageous in that it gives rise to less fly nuisance than the unbalanced fauna where *P. alternata* is alone.

The complete fauna does not deplete the film more than *P. alternata* in the warmer months. Elevated periods of discharge of solids in the effluent indicate elevated periods of activity of the grazing organisms. The material discharged consists of the finely divided dejecta of the organisms, their case skins and dead bodies and fragments of film they have loosened. With the insects the discharge should not be seasonally steady. It is believed that the Psychodas cause their maximum discharge of solids at the emergence of the flies from pupae. With a complete fauna solids discharge will be more steady.

H. HEUKELEKIAN

MECHANISMS OF BACTERIAL FLOCCULATION CAUSED BY PROTOZOA

BY JOHN W. WATSON

Nature, 155, 271–272 (1945)

Several recent reports have been made regarding the flocculation of bacteria brought about by protozoa. In the holotrichus ciliate *Balantiopharus minutus* which causes such flocculation, it has been found that mucus is produced within the peristome, to which the food bacteria adhere before being ingested. The mucus not being diffusible remains in the neighborhood of the ciliates. The increase in the viscosity of the culture medium causes the entanglement and flocculation of bacteria. When floccula containing this protozoan is examined under the microscope bacteria are seen to be cemented together by an amorphous substance which has the characteristics of mucin. Control culture of bacteria without the protozoa shows no flocculation.

H. HEUKELEKIAN

THE MAINTENANCE AND REPAIR OF MECHANICAL PLANT AT SEWAGE PURIFICATION WORKS

By G. A. Hill and M. R. V. Daviss

Institute Sewage Purification * (May 3, 1945)

Owing to shortage of labor, repair work is difficult. For the larger sewage works, which do their own repair work, suitable machine tools are required, viz.: lathes, vertical and radial drill (3 ft. 6 in. arm); shaping machine (18–24 in. stroke); milling machine, power-driven hacksaw; power-driving threading machine (up to 2-inch); also pedestal emery wheel, 6 or 8 in. diam., for fine tools, and 24 in. for heavy work. Various hand screw stocks and dies are necessary for motor car repairs. Portable oxy-acetylene welding and cutting equipment is useful. A blacksmith shop is necessary. A 200 lb. pneumatic hammer is useful. In a large works, a brass caster's shop is desirable.

The various types of equipment needing repair are discussed and suitable methods of packing pumps and lining up shafts, bearings, cross heads, and valves are indicated.

In maintenance, a portable electrically-driven centrifugal pump supplies clean water from final settling basins to a hose for cleaning settling basins, etc. One plant uses four such sets.

For repairs to screen cleaning machanisms and other types of equipment, spare parts should be carried.

For shredding screenings, a disintegrator may be useful. Unless solids are broken down, a non-clog pump may be required.

In sluice gates, 30 × 42 in. or over, a ball thrust bearing under the spindle collar and a single wheel on the spindle nut has lightened the effort of operation.

On all rotating or reciprocating machinery, maintenance and lubrication are required. Reboring cylinders or grinding of crankshaft bearing faces had best be done by firms specializing in such work.

This paper apparently reflects the practice at the Birmingham, Tame and Rea District Drainage Board, of which F. C. Yokes is Engineer.

Langdon Pearse

ANNUAL REPORT OF THE CITY ENGINEER, JOHANNESBURG, SOUTH AFRICA FOR YEAR ENDED JUNE 30, 1944

By E. J. Hamlin

This annual report is unusually brief, because of war conditions. In the five sewage works, the yearly average daily flow has increased from 4 to 18 per cent. In three plants the increase is due to industry. At times oil wastes have caused trouble. In general, there have been few houses built. The usual restrictions on discharge of trade wastes have been somewhat relaxed.

The pilot plant for purification of grease recovered from sewage was shut down after operating twelve months, pending decision on a permanent installation. A pilot plant is proposed to produce methyl alcohol and formalin solution from digester gas.

Langdon Pearse

SIMPLIFIED CONSTRUCTION OF SEWAGE TREATMENT PLANTS ALSO AFTER THE WAR

By W. Kunze

Ges. Ing., 65, 374–377 (1942)

Simplification of construction and reduction in cost is necessary. Long, rectangular reinforced concrete grit chambers can be replaced by brick chambers or tamped con-

* Preprint of the Paper as Presented on May 3, 1945, in Birmingham.

crete wherever the frost line permits. Mechanical settling tanks are frequently unnecessary, especially for smaller communities. Instead of perpendicular reinforced concrete walls and sumps or hopper bottoms, precast concrete slabs can be laid on a 45° angle for walls and similar slabs for flat gently sloping bottoms with gutters in the center. Separate sludge digesters may consist of earthern lagoons, pits or quarries. When gas collection is desired, wooden or precast concrete slabs may be used as floating covers. When a closed digester is required, heat should be provided by injection of hot cooling water or exhaust steam led directly into the tank. No stirring mechanisms or pumps are required. Trickling filters and activated sludge plants should not be constructed or when plants exist the operation drastically curtailed.

WILLEM RUDOLFS

SEPARATION OF SUSPENDED SOLIDS OF MUNICIPAL SEWAGE IN SETTLING TANKS WITH CONTINUOUS FLOW

BY F. PÖPEL

Ges. Ing. 65, 413–416 (1942)

Experiments conducted at the sewage treament plant at Amsterdam show that settling tanks with continuous flow produce best results when the surface loading does not exceed 7.2–7.5 feet/hr. The experiments confirmed that convection currents do not materially affect clarification. It is necessary to destroy the kinetic energy as much as possible by proper baffling.

Since settling tanks are installed to remove settleable solids the expected removal (E_s) can be calculated by the formula:

$$E_s = A \cdot t^{0.2} \cdot E_f^{0.2}$$

where A = total suspended solids
E_f = settleable solids in raw sewage
t = flowing through time.

In round clarifiers with center inlets, the convection currents may aid by utilization of bottom sludge as "floc-filter." The equation for calculation of suspended solids removal is stated to hold for continuous flow as well as for quiescent conditions with only minor changes. Plant experiments indicate that continuously operating sludge removers produce better results than occasionally operated apparatus.

W. RUDOLFS

HUNDRED YEARS CITY SEWERAGE IN HAMBURG

BY H. STRUVE

Ges. Ing., 65, 430–433 (1942)

After the big fire of 1942, Hamburg was the first city in Germany where a community sewerage system was installed and operated by municipal government. The first combined sewers were used many years as examples for other cities. The purpose of the sewerage system was three-fold: (1) to lower the water table and thereby improve living conditions in the houses, (2) to remove surface drainage from the streets, and (3) to carry away sanitary sewage, roof and cellar drainage. The construction of sewers and treatment plants was in five stages. Drainage systems and sewage treatment plants were constructed separately for suburbs and annexed towns. Since 1926, some 16 treatment plants were built for the suburbs, most of them including trickling filters or activated sludge processes. In the city proper, the total length of the combined sewers in

1942 was 1,100 miles and 118 miles of storm sewers with 26,000 manholes, 50 pumping stations and 18 treatment plants. Plants consist of Imhoff tanks, trickling filters and fish ponds.

WILLEM RUDOLFS

A BIOLOGICAL SEWAGE TREATMENT PLANT FOR A SMALL CITY

BY KARL IMHOFF

Ges. Ing., 66 (16) 187–193 (1943)

The treatment plant was designed for 15,000 people with a sewage flow of 39.6 gal. per capita. The dry weather flow received averaged 33 gal. cap., which doubled during rainy weather. A rather high degree of treatment was required. The plant consists essentially of pumping station, coarse screens, grit chamber, two-story tanks, trickling filters, final settling tanks and sludge drying beds. Since two-story tanks are easy to operate and gas collection was not important in this case, the two-story tanks were designed for 1½ hr. detention during the day, providing 3 hr. during the night. Trickling filters with rotary distributors were deemed best. The volume of digested sludge produced amounted to 0.127 gal. cap. day with a moisture content of 90 per cent, or 24 grams (0.05 pound) dry solids cap. day.

WILLEM RUDOLFS

STUDIES ON THE AGRICULTURAL USE OF MUNICIPAL SEWAGE

BY K. SCHULTZE

Arch. Hyg., 130, 244–263 (1943)

Studies pertaining to the detection, flight distance and physical condition of sewage sprayed into the air in finely divided form were made at a number of sewage treatment plants. Application of artificial rain causes part of the finely divided drops to be sprayed high into the air and carried away by wind. The droplets may be carried considerable distances and redeposited in built up areas, vegetable and fruit farms, enter moving vehicles, etc. Experiments at 3 places to determine the actual distance droplets were carried by air currents failed to produce reliable results when bacteriological examinations were made. A dye (Fuchsin) was added to the sewage and droplets collected on glass plates. The size of the droplets was measured. On evaporation of the droplets, salt crystals remained. The formation of salt crystals was considered indicative of sewage. No definite conclusions were reached, but the distances travelled were considerable indicating a positive danger.

WILLEM RUDOLFS

SEWAGE SLUDGE AS FERTILIZER

BY E. MÜLLER

Ges. Ing., 67, 99–103 (1944)

Experiments with sewage sludge at Frankfort-on-Main were made to determine the value of different types of sludges. Sludges used were: (1) raw settled sludge, (2)

partly digested and composted sludge, (3) wet digested sludge, (4) centrifuged digested sludge cake, (5) centrifuged digested, dried and composted sludge, (6) centrifuged digested sludge stored for three years.

The fertilizing and humus values of the sludges as produced were:

No.	Total Org. Solids %	Humus %	N %	P_2O_5 %	K_2O %
1	5.6	2.59	0.25	0.14	
2	29.9	17.2	0.81	0.61	0.14
3	9.1	3.95	0.33	0.15	0.02
4	19.0	7.42	0.42	0.30	0.03
5	27.3	12.85	0.55	0.57	0.06
6	23.2	?	0.93	0.53	0.10

On the basis that the nitrogen content of the sludges is most important from the fertilizing standpoint the quantities of sludge to be applied and the amounts of fertilizers and humus present were as follows:

No.	Sludge Lb./Acre	Containing Lb. N	P_2O_5	K_2O	Humus
1	28,700	176	99		1,840
2	8,800	176	132	31	3,750
3	21,800	176	82	11	2,120
4	17,000	176	126	13	3,130
5	17,600	176	183	20	4,105
6	7,700	176	102	20	?

The losses in fertilizing value and humus content caused by centrifuging, digestion and composting varied materially with different sludges:

No.	% N	% P_2O_5	% Humus
2	79	72	58
3	33	46	22
4	66	55	40
5	73	53	43
6	61	58	62

Partial digestion and composting produced smallest losses. With fresh solids there was little loss, but the solids concentration was low and much water had to be transported. Moreover, this sludge produces odor and extensive fungus growth in the soil could not be prevented. If gas production is required, digestion and composting is best, but the fertilizing value is greatly reduced. It is concluded that the simplest material to use is the centrifuged digested sludge cake.

WILLEM RUDOLFS

FOURTH ANNUAL REPORT, SEWAGE TREATMENT WORKS FOR 1944, GARY SANITARY DISTRICT

By W. W. Mathews

The summary of the operating results for the years 1941 to 1944, inclusive, are given in Table I. Owing to the drought from June to December inclusive, the sewage

Table I. *Summary of Operating and Analytical Results*

Item	1941	1942	1943	1944
Population Served (Est.) Equivalent	100,000	100,000	100,000	100,000
Sewage, m.g.d.	19.37	20.72	21.50	18.83
Suspended Solids Removed, lb.	11,657,667	14,011,858	19,073,538	18,173,772
5-day B.O.D. Removed, lb.	8,276,834	7,927,967	7,869,441	9,734,489
Gas Production, cu. ft.	53,320,100	57,594,800	52,430,600	56,502,200
Average Daily Gas Prod., cu. ft.	146,156	157,790	143,660	154,378
Air, cu. ft. per gal.	0.52	0.46	0.41	0.48
Lb. B.O.D. Removed per 1,000 Cu. Ft.	1.45	1.16	1.20	1.396
Aeration Period, hr.	4.29	4.40	3.90	4.68
Per Cent Return Sludge	29.70	34.00	32.49	34.66
Suspended Solids, Mixed Liquor, p.p.m.	1,557	1,440	1,353	1,221
Final Effluent, p.p.m.				
Suspended Solids	8.2	5.9	10.34	5.13
5-day B.O.D.	9.8	7.2	9.3	6.29
Reduction in Per Cent:				
Suspended Solids	96.12	97.22	96.58	98.40
5-day B.O.D.	94.31	94.72	92.82	96.42
Cost per M.G.	$9.42	$8.79	$8.70	$11.64
Cost per Capita (100,000 Conn.)	0.648	0.665	0.683	0.802
Cost per 1,000 lb. 5-day B.O.D. Removed	7.83	8.39	8.67	8.21

pumped in 1944 was the lowest for the four years. However, more B.O.D. was removed. The gas production averaged 1.54 cu. ft. per cap. per day, or 6.2 cu. ft. per lb., volatile solids added. The primary digesters ranged from 69 to 105° F. on monthly averages.

The sludge gas (619 B.T.U. net) supplied the power for 99.96 per cent of the air blown and 88.08 per cent of the sewage pumped. The value of the gas was estimated at $22,661. The power bill was $11,757. In value of the power requirements the sludge gas supplied two-thirds of the total, but in terms of average load, 80 per cent. The per cent of volatile suspended solids in the raw sludge was 51.51 (higher than 48.02 in 1943 and lower than 57.70 in 1941).

Air dried sludge was again available. 2,167 persons removed 3,502 cu. yd. from the beds (about three-fourths the output). This is below the high removal of 1940 (5,130 cu. yd.), the entire annual output.

The bacterial analyses of the effluent show 41,200 total bacteria per ml. and 96,000 *B. coli* M.P.N. per 100 ml.

Langdon Pearse

STREAM POLLUTION CONTROL BOARD AS IT AFFECTS THE CITIZEN

By Leo Besozzi

Monthly Bulletin, Indiana State Board of Health, **48**, 5 (January, 1945)

The Stream Pollution Control Board was formed two years ago. It consists of six members, one of which is chosen by the voters, the remainder by appointment by the Governor. One of the important obligations of the Board is to protect the citizens against water borne disease. The Board also proposes to attempt to eliminate from water supplies all deleterious substances which might create taste, odor, or other physical nuisances and all substances likely to adversely affect aquatic life or intefere with the recreational uses of the stream. The Board hopes to be able to accomplish this objective for the citizens of the State largely by educational means and by its ability to point out to any offending city, town, or industry the great desirability for the correction of any existing, undesirable condition.

Paul D. Haney

SEWAGE WORKS EQUIPMENT AND SUPPLIES*

ARMCO DRAINAGE PRODUCTS ASSOCIATION

Middletown, Ohio

SERVICE RECORD OF CORRUGATED PIPE SEWERS

Three reasons are given for the increased use of corrugated iron pipe for sanitary sewers: (1) structural strength, (2) added durability and (3) watertight joints.

1. The sewer designer today realizes the importance of building sewers with strength adequate to resist the vibration and impact of heavy truck and trolley traffic, as well as shifting soils and unstable foundations. Major sewer failures as well as expensive maintenance and replacement is attributed to these forces.

Flexible, corrugated iron pipe, with a long and favorable service record in the highway and railway fields, has also been the answer to this vexing problem of structural durability in the sewage works field.

2. Although plain galvanized corrugated iron pipe has been used for storm drains and for many sanitary sewers during the past forty years, its use for acid industrial wastes has not been recommended. Not until the bituminous paved invert was introduced in 1926 and the asbestos-bonding process for bituminous coatings about ten years later, was corrugated pipe actively promoted for sewer use. Today, engineers specify Armco Asbestos-Bonded Paved Pipe with confidence for the toughest soil and industrial waste conditions.

3. With sewage treatment a "must"

FIG. 1.—Replacing a leaky rigid type sewer with 15-in. Armco Paved Invert Pipe in Raleigh, N. C. Three previous installations of rigid pipe had been employed without success.

*Contributed by advertisers in this issue.

FIG. 2.—One of several Armco Asbestos-Bonded sewer outfalls installed in salt water at West Palm Beach, Florida.

after the war, the practical elimination of ground water from sanitary sewer lines is essential. Bituminous coated asbestos-bonded pipe with watertight bolted couplings is the economical answer to this third problem.

There are other features such as light weight, ease of handling, relining with minimum reduction of waterway, a complete line of corrugated pipe fittings, manholes and catch-basins. Copies of a 48-page booklet on Armco Paved Invert Pipe Sewers are available on request from the Armco Drainage Products Association, Middletown, Ohio, or any of its member companies.

BAILEY METER COMPANY

1050 Ivanhoe Road, Cleveland 10, Ohio

METERS AND CONTROLS FOR SEWAGE AND WATER

Open Channel Meters

Recent trends in sewage works design necessitate the use of more open channel type registers. This easily installed, low cost metering device, which may be applied to flumes, weirs, or atmospheric discharge nozzles, is now available both as a direct mechanical register and as a remotely located register.

The direct mechanical register is located at the float tube or still well and is operated by means of a float and cable arrangement. The indicating, recording and integrating features are all driven by direct mechanical connection to the float and cable as illustrated in Figure 1. A cam shaped to correspond to the flow head characteristic of the primary device provides for the use of a uniformly graduated chart.

Remotely Located Register

Increased flexibility of application, together with easy totalizing of two or more flows, is provided by the Bailey Electronic Telemeter Type Open Channel Meter as illustrated in Figure 2. The float and cable operate an electronic transmitter so that the register may be located at a distance from the flume or weir. The transmitter simply positions a movable core in a transformer so that the voltages induced in two secondary windings vary with the position of the core.

An electrical bridge is formed by these windings in the transmitter and the electrical elements in the receiver. This bridge is kept in continuous balance by an electronic amplifier and motor control circuit which operates the motor driven receiver so that its

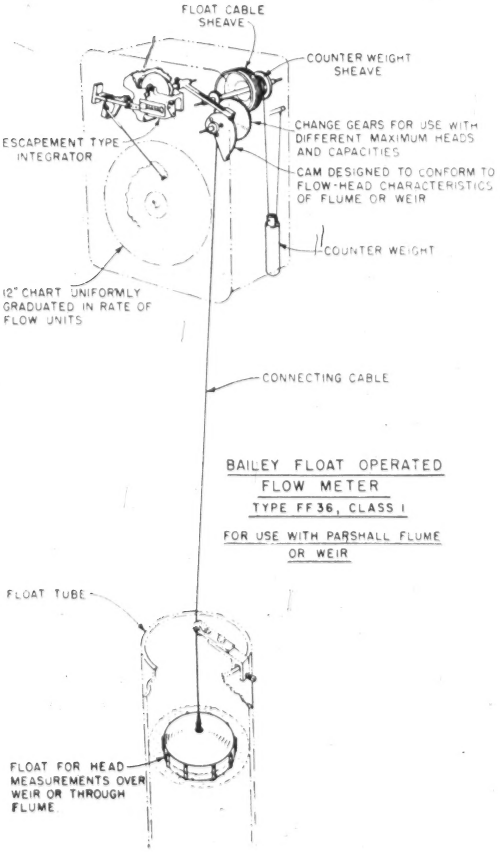

FLOAT CABLE SHEAVE
COUNTER WEIGHT SHEAVE
CHANGE GEARS FOR USE WITH DIFFERENT MAXIMUM HEADS AND CAPACITIES
ESCAPEMENT TYPE INTEGRATOR
CAM DESIGNED TO CONFORM TO FLOW-HEAD CHARACTERISTICS OF FLUME OR WEIR
COUNTER WEIGHT
12" CHART UNIFORMLY GRADUATED IN RATE OF FLOW UNITS
CONNECTING CABLE
BAILEY FLOAT OPERATED FLOW METER
TYPE FF36, CLASS I
FOR USE WITH PARSHALL FLUME OR WEIR
FLOAT TUBE
FLOAT FOR HEAD MEASUREMENTS OVER WEIR OR THROUGH FLUME

FIG. 1.—Direct mechanical register for Bailey Open Channel Meter.

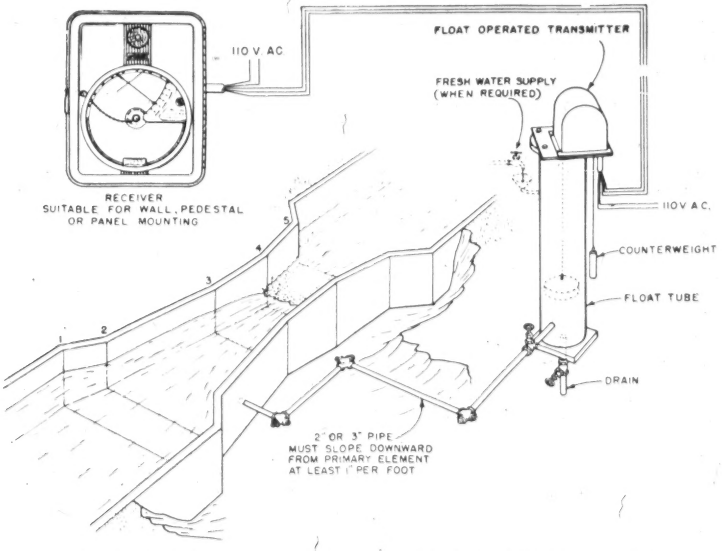


FIG. 2.—Typical installation of Bailey Remotely Located Register operated by electronic telemeter.

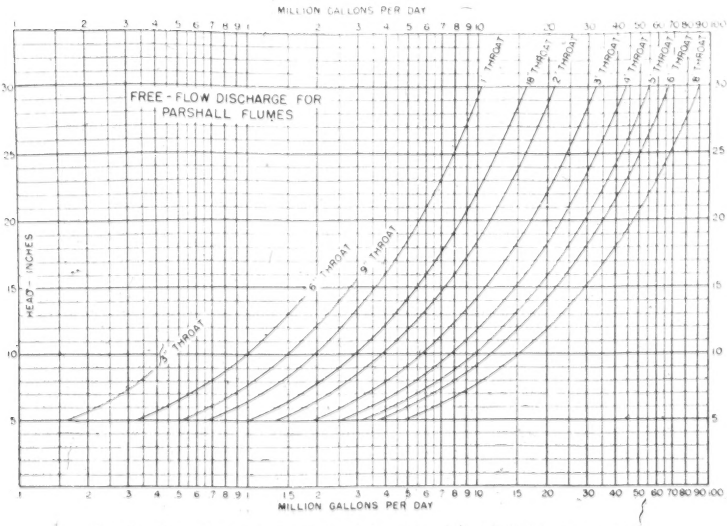


FIG. 3.—Capacity curve for determining size of Parshall Flume required.

position always corresponds to that of the transmitter.

The receiving register is a standard Bailey Electronic Indicating, Recording and Integrating Instrument, which is calibrated to read directly in terms of flow. It is suitable for wall, pedestal or panel mounting. Single or double faced indicators up to 42 in. in diameter are also available.

The Electronic Telemetering System serves as a torque amplifier which requires practically zero input and which provides abundant power for the operation of the recording pens, indicating pointers, control devices, alarm contacts and other instrument features. This characteristic insures accurate operation of the transmitter since there is practically no reaction to oppose movement of the transformer core. The transmitter is a sturdy simple mechanism which may be located out of doors.

Chemical Feed Control

Bailey Open Channel Meters of both the direct mechanical and the remotely located register type may be provided with contacts for simple chemical feed control. They may also be used as the instruments for rate of flow and ratio control. In this case, the instruments involved are provided with air pilot valves which establish air loading pressures corresponding to instrument readings.

Primary Element

Although Bailey Open Channel Meters are well adapted to any open channel primary element, the Parshall Flume as illustrated in Figure 2 is the most popular primary element. This flume, which is sponsored by the U. S. Department of Agriculture, is self-cleaning, easy to build and consistently accurate. Figure 3 has been prepared from the data in recognized publications as a handy reference in choosing the proper size Parshall Flume for the expected free flow discharge in m.g.d.

Capacity Change

The maximum capacity of any Bailey Open Channel Meter can be changed without disconnecting the metering system.

In general, the only limitation on open channel meter capacity is the basic maximum capacity of the primary device and the fact that the head at maximum flow should be at least 5 in. of water to secure adequate power for register operation.

BUILDERS–PROVIDENCE, INC.

(Division of Builders Iron Foundry)

28 Codding St., Providence 1, R. I.

FLO-WATCH WITH WEATHER-PROOF HOUSING

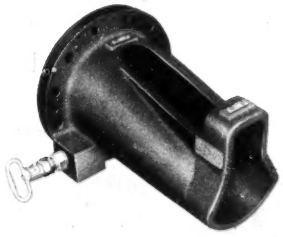
Builders Flo-Watch Instrument is now available in a rugged cast iron case, fully protected from tampering and the weather, thus saving the cost of a separate meter house. The Flo-Watch—a precision float-operated instrument—measures flow through Kennison Nozzles, Parshall Flumes and over weirs. Chemical feeders can be automatically controlled in direct proportion to main line flow, resulting in uniform treatment and substantial savings in chemicals used. The Flo-Watch is furnished with 12-in. diameter chart, and is available with indicator and totalizer if desired. It may

Builders-Flo-Watch Instrument.

also be equipped for remote duplicate readings. Bulletins 318B and TDS 1593.

KENNISON NOZZLE FOR OPEN FLOW

The need for a simple meter, capable of continuous operation on partially filled pipes and open channels—accurate over a wide range and not affected by suspended solids and debris,—resulted in the development of the Kennison Nozzle. This meter is proving ideal for measuring the flow of raw sewage and trade wastes in branch sewers and interceptors, at the sewage inlet to disposal plants, and for metering sludge pumped from settling tanks

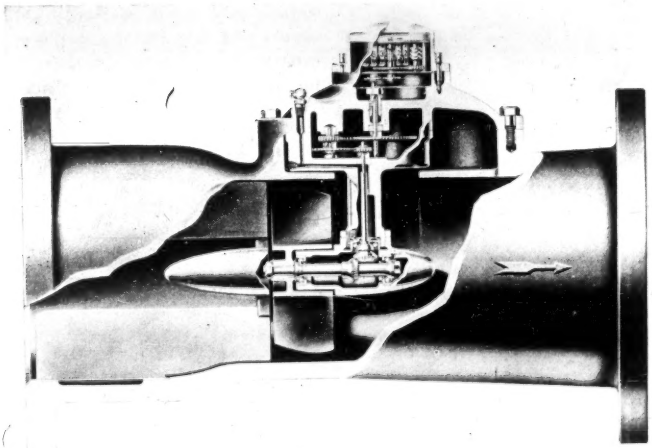


Kennison Nozzle.

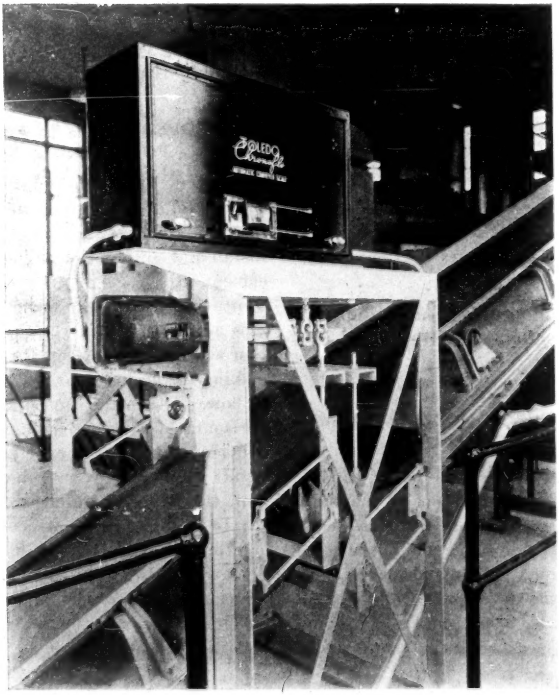
and digesters. The Kennison Nozzle provides permanent, continuous chart records of daily flow conditions—data of immense value for future planning. Bulletin 334A.

PROPELLER-TYPE METER FOR EFFLUENT

Builders Propeloflo Meter is an improved totalizing flow meter complete in itself, relatively low in cost, easy to install and suitable for measuring clear effluent in sewage plants. The unique Venturi design of the meter body creates a more uniform velocity distribution where the flow meets the propeller, making for accuracy over a wide range of flow. The meter can be installed in horizontal, vertical or inclined position provided the line at the meter is full of liquid. Where flow may be intermittent, the Propeloflo Meter resumes accurate metering without readjustment or attention when the drain line is refilled. The Propeloflo Meter has ample power to pace proportioning chemical feeders or to drive devices for remote recording. Bulletin 350.



Propeloflo Meter.



Builders Toledo Chronoflo Conveyor Scale.

WEIGHING SLUDGE IN TRANSIT

Builders Toledo-Chronoflo Conveyor Scale is in effect an accurate flow meter for weighing sludge cake in transit. It may be installed with any belt conveyor system to totalize the weight of dry sludge discharged from vacuum filters. A Chronoflo Transmitter sends to the totalizer weight variations in belt loading as measured on the scale. At the same time, the Belt Speed Compensator detects any change in belt speed and transmits it to the totalizer. These two variables are combined and translated into an extremely accurate registration of weight on the counter of the indicator, located at any convenient point. The large, easy-to-read figures show at all times the total weight of sludge transported on the conveyor belt. Bulletin 322.

NEW BULLETIN ON MEASUREMENT, CONTROL, AND CHEMICAL TREATMENT OF SEWAGE AND SLUDGE

Builders-Providence, Inc., has prepared a new Bulletin No. 287A with the definite aim to include material of real value to engineers and others engaged on sewage treatment problems for both large and small communities. Bulletin 287A is fully illustrated and describes new types of indicating, recording and integrating flow instruments devised by Builders engineers for application to such primary units as Venturi Tubes, orifices, Kennison Nozzles, Parshall Flumes and conveyor scales. Useful reference diagrams are also included. A copy of this interesting and useful new Bulletin may be had by writing Builders-Providence, Inc.

THE CARBORUNDUM COMPANY
REFRACTORIES DIVISION

Perth Amboy, N. J.

"ALOXITE" AIR DIFFUSER TUBES AND PLATES

"Aloxite" ceramically bonded aluminum oxide porous diffusers have become a standard for all types of sewage aeration. This is primarily a result of The Carborundum Company's established policy to keep abreast with the varying requirements of aeration systems and provide an engineering service to engineers and plant superintendents.

These diffusers are structurally strong and rugged to withstand any reasonable installation and operation handling without danger of breakage. They are permanently resistant to corrosion or attack by any solution or gas found in sewage. They will also withstand types of acid treatment, chlorination, reburning and acetylene torch spalling, which methods have been used for cleaning.

"Aloxite" diffusers are inherently uniform (produced by methods developed for abrasive wheels which must be uniform) so that uniform air diffusion is assured. They also have low wet pressure loss for any given permeability grade. These are small money saving factors but they are important because of the cumulative effect.

Diffuser tubes (Figure 1) are available in several sizes as illustrated to conform with aeration tank requirements and to fit various types of assembly equipment. Tubes are being used more extensively than plates because of lower overall cost and simplicity of installation and removal for servicing.

Diffuser plates (Figure 2) are manufactured in the standard 12-in. by 12-in. by 1-in. thick size illustrated;

also, in special sizes as may be required by special aeration tank designs. Half size plates are often utilized where air

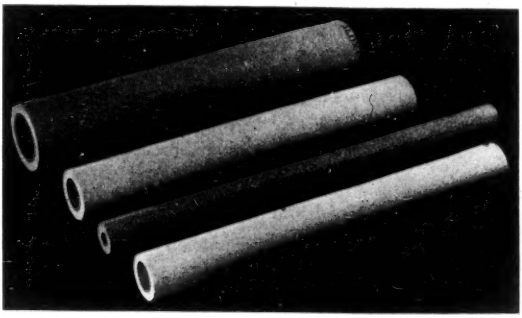


FIG. 1.—"Aloxite" diffuser tubes.

requirements are low or in combination with mechanical aerators. Special long plates are also available for the

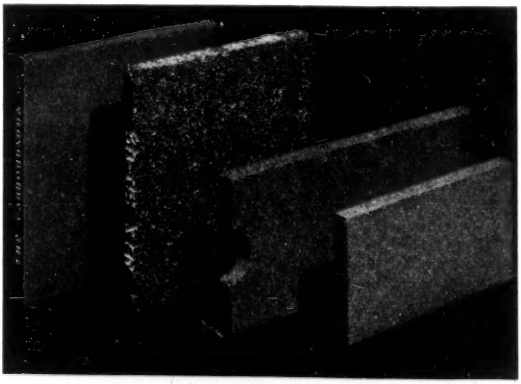


FIG. 2.—"Aloxite" diffuser plates.

type of cast iron individual plate holders used in most Canadian plants.

Manufacturers of aeration or diffuser equipment have consistently furnished "Aloxite" diffuser tubes or plates incorporated as an integral part of complete diffuser equipment. The Carborundum Company does not supply plate holders nor any type of diffuser tube assembly equipment. Manufacturers of all such equipment, of which there are now many improved types, will gladly quote on and furnish "Aloxite" diffusers.

For further information write for Engineering Bulletin No. 1.

CHAIN BELT COMPANY

Milwaukee, Wis.

WATER, SEWAGE AND INDUSTRIAL WASTE EQUIPMENT—PORTABLE DEWATERING PUMPS—CONCRETE MIXERS—CHAIN AND SPROCKETS FOR CONVEYORS AND MACHINERY DRIVES

THE REX AERO-REDUCTION PROCESS

The REX Aero-Reduction Process—low rate high capacity filtration—has been very successfully applied to the treatment of industrial wastes of varying nature. A typical example is the installation at Cokato, Minnesota, now starting its 6th season, where a canning plant waste is lagooned and recirculated through an Aero-Filter.

1943 operating data from this plant shows the raw waste entering the lagoon to have a 5-day B.O.D. of about 4,000 p.p.m. Approximately 723,760 pounds of B.O.D. were delivered to the lagoon during the canning season. At the close of the season, 112,290 pounds were still present. The last sample (taken just prior to the setting in of winter) showed that only 1,565 pounds remained. The average reduction in B.O.D. accomplished by the filter was 218 p.p.m. The volume pumped through the filter each day was 2,000,000 gallons. Thus, the total removal by the filter was approximately 3,500 pounds per day, or one pound per square foot per day.

About a year after construction of the waste treatment plant, the domestic plant was rebuilt. It was constructed adjacent to the waste treatment plant, and arrangement was made to discharge the partially purified waste from the lagoon to the domestic sewage treatment plant for further treatment in case of necessity. The flow diagram is now as shown in Figure 1.

THE REX VIBRATING SCREEN

The REX Vibrating Screen for waste treatment (Figure 2) is removing onion skins from wash water in a dehydration plant. This is a typical application of such equipment either for reclamation of product, clarification of water for re-use, or its pre-treatment prior to disposal in municipal sewage systems.

THE REX WASTE-WATER OIL SEPARATOR

The REX Waste-Oil Separator is a specialized design of settling tank and equipment for this industrial use. Uti-

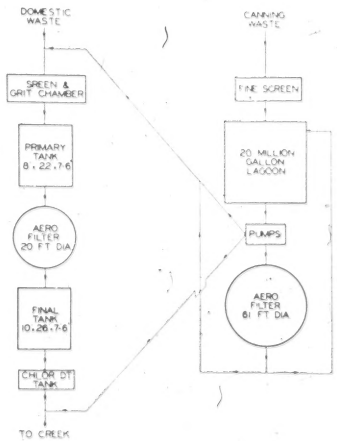


FIG. 1.—Flow diagram of REX Aero-Reduction Process as employed at Cokato, Minn.

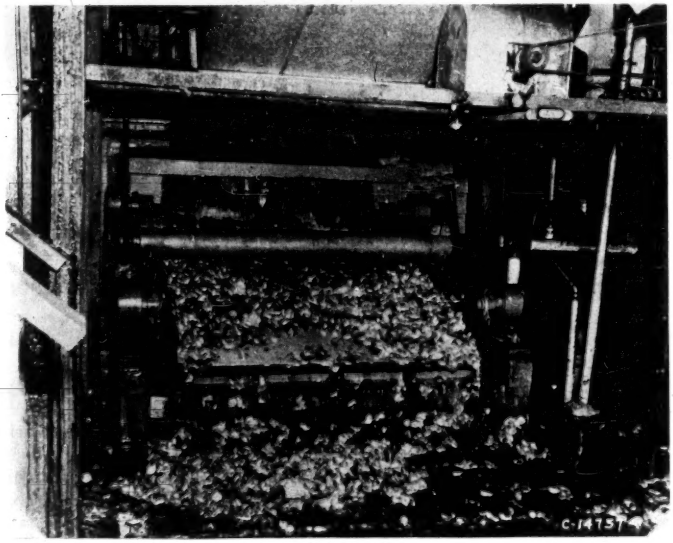


FIG. 2.—The REX Vibrating Screen.

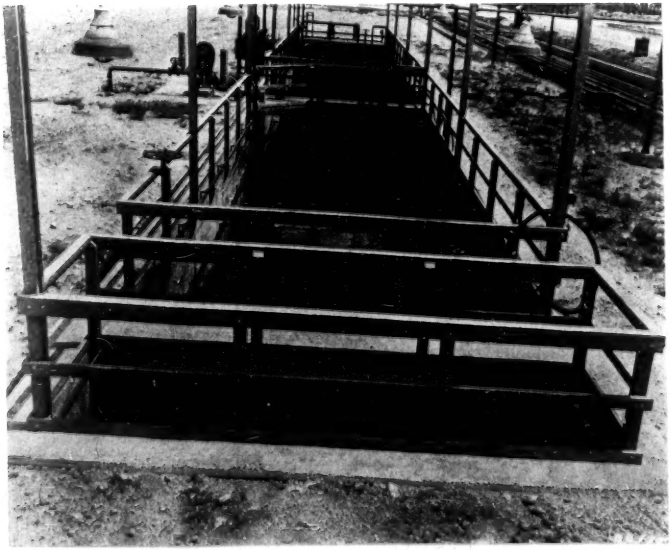


FIG. 3.—The REX Waste-Water Oil Separator.

lizing the time-proven, efficient rectangular tank and conveyor sludge collector mechanism, this unit not only collects and removes the heavy waste sludges, but also reclaims large volumes of valuable floating oil. This process is made practical by special influent and baffle construction, skimming pipes, and operating mechanisms.

Removals of 98 to 99 per cent of incoming oil can be expected under suitable conditions. Figure 3 pictures an installation of this type at a large oil refinery.

CHICAGO PUMP COMPANY

2314 Wolfram St., Chicago 18, Ill.

"PACKAGE" SEWAGE PLANTS, WIDE BAND AIR DIFFUSION SYSTEM WITH SWING DIFFUSERS, COMMINUTORS FOR SCREENING AND CUTTING COARSE SEWAGE SOLIDS, SCRU-PELLER PRIMARY SLUDGE PUMPS, FLUSH-KLEEN SEWAGE LIFT STATIONS; RAW SEWAGE PUMPS, PLUNGER SLUDGE PUMPS, WATER SEAL PUMPING UNITS

"Package" sewage treatment plants (Figure 1), originated and perfected exclusively by the Chicago Pump Company, are becoming increasingly popular for small municipalities, institutions, airports, industrial plants and housing projects. The first Chicago "Package" plants were installed more than ten years ago, and there are now more than a hundred of these plants in successful operation. This background of experience and successful performance of Chicago "Package" plants is protection for the engineer and for the municipality. Ingenious patented features developed during the last ten years are responsible for the successful performance of Chicago "Package" plants. The first cost of these plants is low. They require a minimum of operating supervision, produce a sparkling clear effluent, are free from flies, odors or unsightly appearances and may be safely located near dwellings.

Our competent staff of sanitary engineers devotes its time exclusively to laboratory and field research and to supervising the initial operation of new sewage treatment plants. In addition our engineers maintain close contact with the superintendents of Chicago-equipped plants and cooperate with them for the successful operation of their plants. We have complete records of the operation of Chicago-equipped plants, and these have proved to be invaluable reference data.

PILOT PLANTS

We have continued the operation of pilot plants for the solution of unusual sewage treatment problems. The aeration period and other variable operational functions can be controlled at these plants, and the data accumulated make it possible to determine the proper operation procedure for maintaining the characteristic high degree of purification.

Many Chicago-equipped industrial waste treatment plants are in successful operation as a result of pilot plants set up in cooperation with various industries to determine the proper method of treating special industrial wastes.

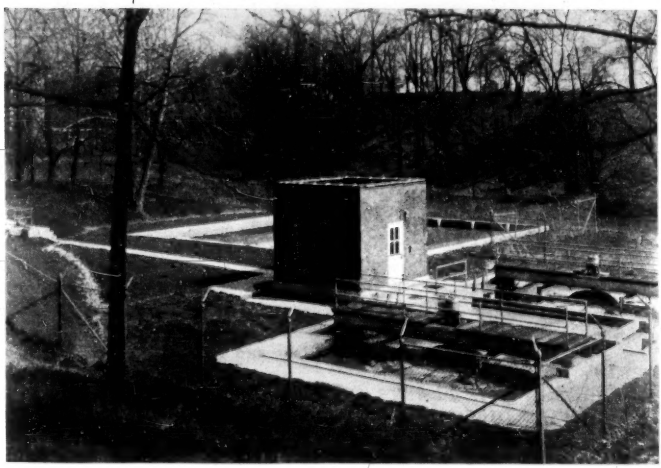


FIG. 1.—A Chicago "Package" sewage treatment plant, illustrating the compactness and neat appearance of this type of plant for small communities. These plants are free from flies and odors, produce a sparkling clear effluent and requires a minimum of operating supervision.

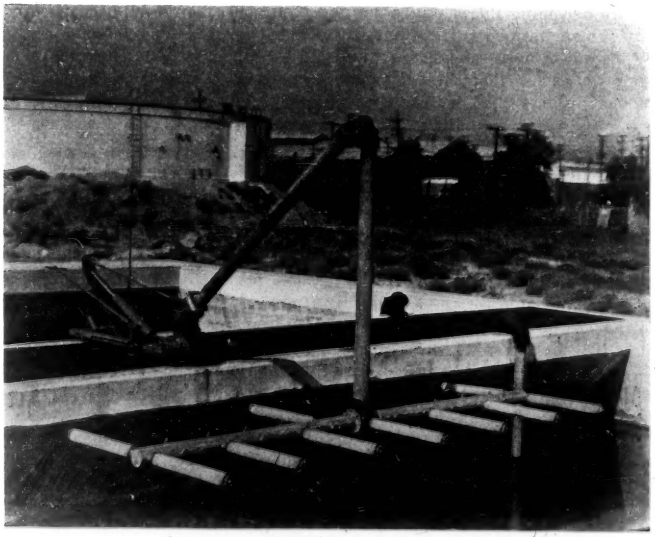


FIG. 2.—The new hydraulically operated Swing Diffuser Hoist developed by the Chicago Pump Company shown in the operating position on the walkway of an aeration tank.

GREASE REMOVAL

Good results are being obtained with the grease removal process developed last year. The process is a combination of aeration and a specially constructed tank. It requires a minimum of equipment.

"FLUSH-KLEEN" IMPROVEMENTS

The inflow capacity of the Chicago Pump Company Flush-Kleen sewage lift station pump has been greatly increased by placing a bypass to the wet basin between the automatic strainer and the pump. The inflowing sewage thereby passes through the bypass into the wet well rather than through the pump casing.

The sewage inlet is connected to the discharge pipe of the Flush-Kleen instead of to the basin as in ordinary sewage pumps; therefore, the raw sewage flows into the discharge line. A strainer just ahead of the pump stops the solids but allows the water to pass through the bypass into the basin. The solids accumulate in the strainer chamber located in the discharge line of the Flush-Kleen.

When the pump starts it pumps the water from the basin through the discharge line. As the water passes through the strainer chamber it flushes out the solids that have accumulated there. A check valve in the bypass prevents sewage being pumped back into the wet basin and another check valve in the inlet prevents the sewage from being pumped back into the inlet line. These are improved check valves that cannot be held open by rocks or sticks.

Another advantage of the new bypass is that it reduces the pump pit depth requirement by one foot.

Flush-Kleens are installed in duplex sets with an "automatic alternator" to transfer the operation from one pump to the other. Only one pump operates at a time. Sewage flows into the basin through the discharge line and bypass of the idle pump.

Flush-Kleens have many advantages over other types of sewage pumps. They cannot clog, because stringy material and coarse solids are not handled by the impellers. Only water passes through the pump.

Life of a Flush-Kleen is about twice that of other sewage pumps. When coarse solids wedge between impeller and casing of an ordinary sewage pump, the pump is thrown out of balance and the excessive strain wears the impeller, casing, bearings, shaft and motor. The Flush-Kleen is not subject to severe strain and wear because the pump handles water only.

The Flush-Kleen consumes less power than other sewage pumps. When coarse solids wedge between the impeller and casing of an ordinary sewage pump, it takes an excessive amount of current to operate the pump. There are no strains or undue loads put upon the Flush-Kleen, because the pump handles water only.

Hundreds of sets of Flush-Kleens have been installed on aircraft carriers, troop transports, hospital ships, and other vessels under the war shipbuilding program.

IMPROVED SWING DIFFUSER HOIST

An improved portable, hydraulically operated swing diffuser hoist (Figure 2) has been produced. The new hoist is simpler in construction, lighter, easier to handle, and greatly simplifies the hoisting function in swing diffuser operation.

The hoist is of the hydraulic ram type suitable for outdoor operation. It engages the movable member of the swing joint and raises the entire swing diffuser assembly completely from the tank by exerting leverage upon the movable member.

The hoist body has a welded tubular frame and is supported on three wheels with coil spring suspension to compensate for minor variations in the surface

level of the concrete. The hoist is provided with suitable fittings so that it can be readily connected or disconnected from the swing joint in either the up or down position, without the use of tools.

The oil pump for the hoist is a four piston radial type pump either direct connected to an electric motor, or mounted for manual operation. An automatic relief valve is provided for the pump.

A three position (up-hold-down) control valve is used to control the operation of the hoist. The valve handle automatically returns to the "hold" position at all times except when it is manually held in either the "up" or "down" position, thus assuring complete safety in raising or lowering the swing diffusers.

SEWAGE SAMPLER IMPROVED

The Tru-Test Sewage Sampler has been redesigned and improved by the Chicago Pump Co. to take samples automatically and accurately in proportion to the flow through the plant. It gives representative samples containing the correct proportion of suspended solids and dissolved organic matter. Samples can also be taken to show accurately the changes in character of the raw sewage during the day and the effectiveness of the various stages of treatment as the sewage passes through the plant.

In addition to the improvement in the accuracy of sampling, the parts of the sampler have been made more accessible and refrigeration for the samples can be installed for those who desire it.

The sampler can be controlled accurately by any one of the following three methods:

(1) By utilizing the difference in pressure through a flow meter.

(2) By the variation in the level of the liquid in the tank or channel.

(3) By manually setting the sampler to take samples at any desired frequency.

CLAY PRODUCTS ASSOCIATION

111 West Washington Street, Chicago 2, Illinois

EXTRA STRENGTH CLAY PIPE FOR HEAVY LOADS

The recent addition of extra strength pipe to the clay pipe line provides increased flexibility and lower costs in sewer and drain construction. Extra strength clay pipe eliminates to a great extent the necessity and cost of cradling pipe in deep trenches or unstable soils. It is also ideal for use under highways, railways, airports and other places where heavy loads are encountered. The ease with which construction can switch from standard to extra strength clay pipe and vice versa saves much time and cost.

Extra strength clay pipe is made of the same fine clays that are used in the manufacture of standard strength clay pipe and is vitrified in the same way . . . but the walls of the pipe are considerably thicker. This results in a pipe of great crushing strength which is completely inert to rust, rot and corrosion.

Extra strength clay pipe joins with standard strength pipe without special adapters or fittings. It is available in all standard sizes and fittings. It conforms with *A.S.T.M. Tentative Speci-*

DIMENSIONS AND CRUSHING STRENGTH REQUIREMENTS FOR EXTRA STRENGTH CLAY PIPE

Nominal Size, in.	Laying Length		Maximum Difference in Length of Two Opposite Sides, in.	Outside Diameter of Barrel,[b] in.		Inside Diameter of Socket at 1/2 in. Above Base, in.	
	Nominal, ft.	Limit of Minus Variation,[a] in. per ft. of length		Min.	Max.	Min.	Max.
6	2, 2 1/2, 3	1/4	3/8	7 1/16	7 7/16	8 3/16	8 5/8
8	3	1/4	7/16	9 1/4	9 3/4	10 1/2	11
10	3	1/4	7/16	11 1/2	12	12 3/4	13 1/4
12	3	1/4	7/16	13 3/4	14 5/16	15 1/8	15 3/4
15	3, 4	1/4	1/2	17 3/16	17 13/16	18 5/8	19 1/4
18	3, 4	1/4	1/2	20 5/8	21 7/16	22 1/4	23
21	3, 4	1/4	9/16	24 1/8	25	25 7/8	26 3/4
24	3, 4	3/8	9/16	27 1/2	28 1/2	29 3/8	30 3/8
30	3, 4	3/8	5/8	34 3/8	35 5/8	36 1/2	37 3/4
36	3, 4	3/8	11/16	40 3/4	42 1/4	43 1/4	44 3/4

Nominal Size, in.	Depth of Socket, in.		Thickness of Barrel, in.		Thickness of Socket at 1/2 in. from Outer End, in.		Average Strength, min., lb. per linear ft.	
	Nominal	Min.	Nominal	Min.	Nominal	Min.	Three-Edge-Bearing Method	Sand-Bearing Method
6	2 1/4	2	11/16	9/16	1/2	7/16	2000	2850
8	2 1/2	2 1/4	7/8	3/4	9/16	1/2	2000	2850
10	2 5/8	2 3/8	1	7/8	5/8	9/16	2000	2850
12	2 3/4	2 1/2	1 3/16	1 1/16	3/4	11/16	2250	3200
15	2 7/8	2 5/8	1 1/2	1 3/8	15/16	7/8	2750	3925
18	3	2 3/4	1 7/8	1 3/4	1 1/8	1 1/16	3300	4700
21	3 1/4	3	2 1/4	2	1 5/16	1 3/16	3850	5500
24	3 3/8	3 1/8	2 1/2	2 1/4	1 1/2	1 3/8	4400	6300
30	3 5/8	3 3/8	3	2 3/4	1 7/8	1 3/4	5000	7100
36	4	3 3/4	3 1/2	3 1/4	2 1/16	1 7/8	6000	8575

[a] There is no limit for plus variation.

[b] The average actual inside diameters of pipe having the nominal thickness of barrel shown in Table II may be smaller than the nominal sizes.

fications for Extra Strength Clay Pipe, A.S.T.M. Designation: C 200–41T and with *Federal Specifications for Clay Sewer Pipe SS–P–361a, Table II.*

The preceding table of dimensions and crushing strength requirements for extra strength clay pipe shows the wide range of standard sizes and the great crushing strength.

Complete specifications and other information will be gladly sent to those interested.

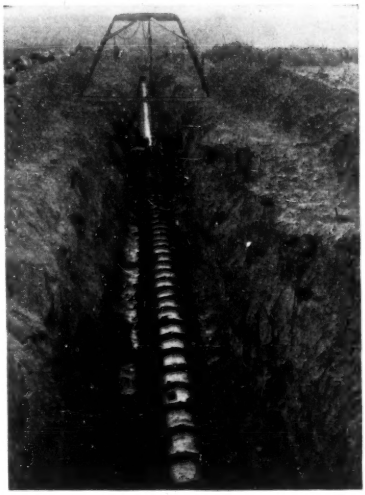


FIG. 1.—Cradling and special handling are eliminated when extra strength clay pipe is used in wide and/or deep cuts, construction under highways, railroads, airports and other places where extreme loads are encountered or where soil conditions require a pipe with a strength well above normal.

DE LAVAL STEAM TURBINE COMPANY

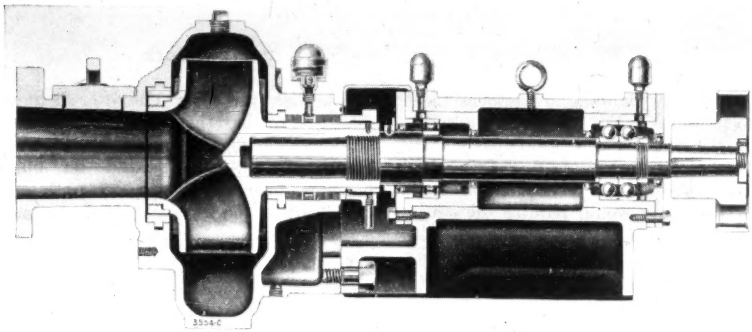
Trenton, N. J.

SELECTING A SEWAGE PUMP FOR THE LOWEST ULTIMATE COST

The practice of awarding equipment contracts to the lowest bidder undeniably protects the purchaser from overcharging, but does not necessarily assure him of the most satisfactory installation, or even the lowest cost, when ultimate costs rather than first costs are counted. This is particularly true when sewage pumps are purchased on the basis of somewhat indefinite specifications, covering little more than the head and capacity requirements. The sewage pump is expected to operate more or less continuously throughout a longer period of years. Outages caused by pump failure are apt to endanger public health, in addition to involving expense and trouble, and even small differences in efficiency eventually overbalance seemingly large differences in initial cost.

Although the purchase of sewage pumps is apt to receive less engineering attention than that of large water works pumps, the service encountered by the former is, in some respects, more severe. Sewage pumps must handle liquids containing a high percentage of foreign matter and grit, and the pumps usually receive but little attention.

It follows that a casing split along the axis of the shaft is preferable to a transversely split casing requiring breaking of piping connections if ever it is necessary to open the pump to remove obstructions or to inspect the working parts; a pump fitted with renewable wearing rings is preferable to one in which unavoidable wear, due to passage of dirt or grit, leaves no other alternative than the renewal or rebuilding of the impeller and machining



Axial section, De Laval clogless sewage pump.

of pump case, or the sufferance of seriously lessened efficiency. A pump employing a stiff, heavy shaft, supported by substantial bearings, is better able to withstand the shock and unbalance caused by passage of large heavy objects than is a pump of lighter and cheaper construction.

These and many other desirable features are incorporated in De Laval Clogless Pumps designed for sewage service. Like the well known De Laval water works pumps, these pumps are built to the highest quality standards.

W. S. DICKEY CLAY MANUFACTURING COMPANY

Kansas City, Mo.

DICKEY EXTRA STRENGTH VITRIFIED CLAY PIPE

The W. S. Dickey Clay Mfg. Co. of Kansas City, Mo., has developed and is now producing an extra strength vitrified clay pipe which complies with all the requirements of Federal Specification SS–P–361a, Table II.

This new durable extra strength pipe provides the additional strength needed under extreme load conditions in sewers, airport drainage, highways and railroad culverts. It is designed to socket with double strength A.S.T.M. pipe or pipe conforming with Federal Specification SS–P–361a, Table I, for standard strength, thereby permitting the use of this extra strength pipe in such sections of a construction project where extreme load conditions require the additional load-bearing qualities which it provides. In addition to the two-fold advantage provided through strength and durability, it will resist attack by acids, gases, corrosion, or any other chemical elements.

In addition to extra strength pipe, we will continue to produce and provide for your needs Dickey quality double strength A.S.T.M. pipe, which will likewise comply with Federal Specification SS–P–361a, Table I. We are also producing a new streamlined high-speed drainage material known as "Skip Pipe."

Literature on all Dickey products will be gladly furnished upon request.

THE DORR COMPANY

570 Lexington Avenue, New York 22, New York

Postwar planning of sewage treatment works is in full swing in all parts of the country and municipal officials seem more sewage treatment conscious than ever before. The general trend of the times would require the equipment manufacturer to come up with something new and novel—a distinctive postwar product. New products will appear without doubt, but they must be the result of long and continued development. Sewage works must operate continuously over a long term of years and the equipment in them must perform efficiently with a minimum of maintenance. The annual appropriation for equipment maintenance is an important item in the operating budget of any plant and high costs for upkeep may soon offset any saving in first cost. The postwar plant, as we see it, should combine the experience of the past with new ideas which have been thoroughly demonstrated.

For a number of years The Dorr Company has devoted considerable time to a study of its equipment in existing installations with the object of reducing maintenance and repairs not only in the present units, but also in any new designs. Changes in minor details are constantly being made to every Dorr unit used in sewage treatment. For example, Dorr Flocculators originally were provided with submerged drive chains, made of the best corrosion resistant alloys available, but under the severe operating conditions to which they were subjected, these chains would wear out in a couple of years. We found that by extending the shafts through the walls of the basin and using a stuffing box, the chains could be placed in a dry well, readily accessible for inspection and lubrication. As a result installations have operated up to 7 years without a cent for repairs.

Likewise, the Dorr Clarifier is now designed so that the entire load of the sludge removal mechanism is carried on a turntable supported on ball-bearings operated in an oil bath entirely out of the sewage. Maintenance costs have been reduced lower than ever and repairs are practically nil. There are many instances where Dorr Clarifiers have operated continuously for years without a shutdown.

The Dorr Clarigester (Figure 1) is rapidly attaining a similar record. This unit combines sedimentation and digestion in a single structure with a concrete tray and special one-way sludge trap separating the two compartments. It has been likened to a mechanical Imhoff tank but one major difference exists. The digester compartment of a Clarigester may be heated as easily as if it were a separate tank. Then, too, no sludge pump is needed to transfer the sludge to the separate digester. With automatic scum removal, it is an ideal answer to the question as to what to install for the primary step in a small community where maintenance and repairs must be kept down.

The Dorr Detritor for grit removal is now equipped in larger sizes with Torq arms, a feature well known in metallurgical fields where heavy loads of solids are the rule. This permits the Detritor to handle the heavy shock loads of grit without overloading the mechanism. The arms simply rake out the solids at a uniform rate over a longer period of time.

Other Dorr machines such as the Clariflocculator (Figure 2), fine screen, distributor and digester have been examined in detail to improve their mechanical performance wherever possible and to reduce maintenance and repairs. We believe that

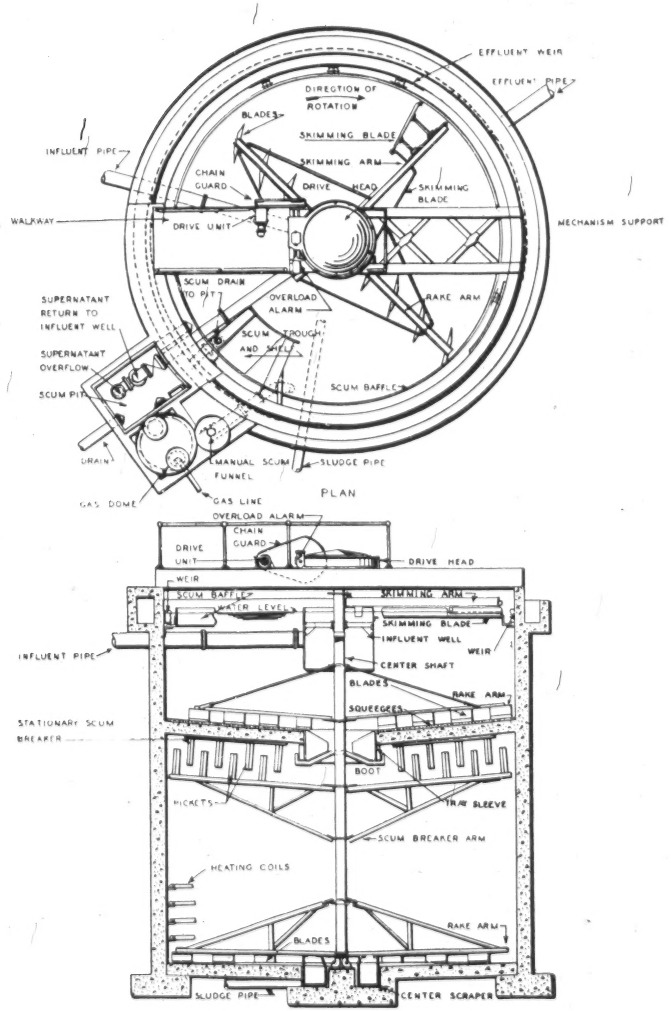


Fig. 1.—The new Dorr Clarigester.

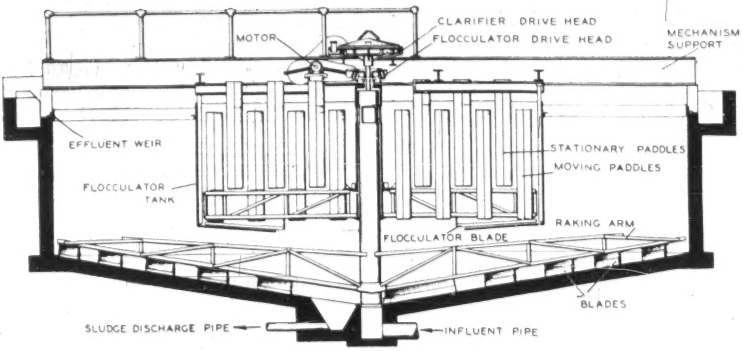


FIG. 2.—The Dorr Clariflocculator.

this procedure will aid materially in keeping down operating costs regardless of the process of sewage treatment. It will make the taxpayer's dollar go farther towards getting good operation.

Aside from bringing the efficiency of the time-tested Dorr equipment to its peak, we have been steadily at work on new developments. Last year we mentioned the Vacuator, the two-in-one Clarifier and combination plants for treatment of industrial wastes. Progress is being continued on these units, particularly the Vacuator. Full scale plant tests with a Vacuator over an 8-month period have just been concluded and the results will give us a better scientific basis for predicting performance on future installations.

A new design of Dorr Digester is soon to be introduced and it will be offered first for smaller plants. The design will combine gas storage of about one-third of total daily production with high capacity mixing in a single tank. It should banish scum problems in a digester, yield a good supernatant suitable for return to the plant and yet require very little attention. It will incorporate only proven principles.

Dorr Monorakes for rectangular sedimentation tanks have been standardized for units from 10 ft. up to 80 ft. in width with lengths from 30 ft. for the narrow units up to 300 or 400 ft. for the wider units. Designs have been completely overhauled with the best features retained from the previous installations, many of which are over 10 years old. The Monorake is patterned after other Dorr machines in that it adheres to the principle of avoiding submerged bearings.

Flash drying of sewage sludge for fertilizer bids fair to be popular in postwar plants. The C-E Raymond Flash Drying System marketed by The Dorr Company possesses extreme flexibility and at reasonable cost. Newer designs now available for postwar projects have been greatly simplified where drying only is wanted. This equipment has an enviable record for continuous operation under overloaded conditions and no money has been spared in the design to keep down maintenance and repairs.

As we approach the much heralded postwar period, The Dorr Company states as its prime objective, the desire to furnish equipment designed for the work to be performed and built to operate with a minimum of upkeep.

ECONOMY PUMPS, INC.

Hamilton, Ohio

VERTICAL NON-CLOG OPEN SHAFT PUMPS

Engineers familiar with pump design and construction will recognize many provisions for increased efficiency, greater accessibility, and reduced maintenance costs in the present design of Economy non-clogging pumps—the result of more than thirty years of intimate contact with operating problems.

The pump casing or volute is of semi-steel especially designed to handle efficiently sewage containing a large percentage of solids, without clogging and with minimum of wear. It is arranged for use with impellers ordinarily of cast iron or bronze, two-blade wide waterway type, locked tight on the shaft taper with a countersunk nut so that there are no protruding hubs or surfaces about which rags or strings may twist. The weight of the shaft and impeller is carried on two widely separated anti-friction bearings, which are designed to carry any thrust which may be present in addition to the radial load. The shaft is of alloy steel, heat-treated, turned and ground all over. The reliability of the heavy shaft and bearings is increased by the addition of the shock absorber or emergency bearing.

The shock absorber consists of two concentric sleeves fitted with a liberal running clearance; the inner being a steel journal screwed and locked to the impeller hub while the outer is securely fitted into the casing. Both are completely renewable. A straight flanged suction fitting with large quick-acting cleanout opening is provided as standard equipment.

All Economy non-clogging pumps are guaranteed for efficiency and capacity and against defects in workmanship and material. Careful inspection and a complete factory running test prove that the pump will perform efficiently both hydraulically and mechanically when installed. Further details may be obtained by writing for Catalog No. F245.

SINGLE STAGE DOUBLE SUCTION PUMPS

Economy double suction pumps are of the horizontal split case, single stage design with both suction and discharge nozzles in the lower half of the case. The entire rotor, cover and parts subject to wear may be removed without disturbing the pipe connections or alignment of pumps and driving unit, reducing to a minimum the time required for inspection or replacement of parts and avoiding expense due to shut-downs and consequent delays.

The hydraulic design can be shown only by the characteristic curves taken from test records. The curves indicate performance from impellers designed to meet the general requirements in this field. However, there are available a number of impellers for each pump case to meet special operating conditions under varying capacity or discharge head. In this way our engineering department is able to make impeller selections for practically every job without delay or extra cost to the customer—an important item.

Consideration has been given to the best operating speeds when electric motors, gas engines, steam turbines or belt drive are used. Standard recommendations listed cover speeds from 390 r.p.m. to 3,500 r.p.m., depending upon the duty to be performed. The mechanical details vary somewhat in the different sizes but a uniform standard of workmanship is maintained throughout the line.

Every Economy pump is tested in accordance with the standards of the Hydraulic Institute and the A. S. M. E.

The test is run under conditions duplicating as nearly as possible those of the actual installation. The test is of sufficient duration to insure satisfactory mechanical operation as well as correct capacity at the rated level. All measurements are taken in the most approved manner. Calibrated nozzles with pitot tubes are used for the smaller pumps and venturi meters for the larger pumps. Power readings are taken by approved methods; all rating tests are run with dynamometers. Water or mercury columns are used wherever practical for low head or suction readings; gauges, when used, are dead weight tested.

The method of handling Economy orders is a factor in securing correct applications. Every order passes through the hands of the engineering department for case and impeller recommendation before the shop order is issued.

Further information may be obtained by writing for Bulletin No. A145.

NEW PUMP DATA BOOK NOW AVAILABLE

The 1945 Edition of Economy's *Pump Engineering Data* handbook is now available upon request. This 416-page reference book has been expanded and improved over previous editions by the inclusion of tables and diagrams to meet every need of the pump user. Coverage is afforded pumping applications in sewage and water works, power plants, irrigation, general industry and other purposes. Liberal space is devoted to general hydraulic data and recommended layouts are provided for guidance in design of pumping installations.

This convenient reference will find extensive use by sewage works engineers and operators. Write today for a copy.

THE EIMCO CORPORATION

634–666 South Fourth West Street, Salt Lake City 8, Utah

EIMCO VACUUM FILTERS

Owing to its physical and chemical properties, sludge yields its water grudgingly and drainage and evaporation proceed slowly. Therefore, more rapid methods of dewatering are desirable.

Of the methods of dewatering sludge more rapidly than on beds, the one now in most common use is the vacuum filter. In this the water is drawn by suction through a wool or canvas filter medium with openings sufficiently fine so that practically no suspended matter passes through. The general type of vacuum filter consists of a filter drum hung suspended in a vat containing the sludge to be dewatered. Radial partitions divide the filter drum into compartments, each connected by individual pipe lines to a multiple-valve hub so that suction or pressure may be applied automatically and alternately to any compartment as desired. The surface of the drum is covered with a filter medium through which the water is sucked as the drum revolves through the sludge in the vat, and the solids are left deposited on the surface of the drum in a layer or cake ½ in. or more in thickness, which layer or cake is dried by sucking air through it after it has emerged from the vat, and then is peeled from the drum over a scraper. An agitator in the sludge vat keeps the solids there from stratifying; Eimco uses mechanical agitators, but excess air from blowers has been used satisfactorily in some cases.

Vacuum drum filters are built in drum diameters from 3 ft. to 12 ft. and

in drum lengths from 1 ft. to 16 ft. The filter drum is ordinarily equipped with variable speed transmission and revolves from 1 to 12 r.p.m., depending on the particular installation. The performance is measured by the pounds of dry solids in the sludge cake produced per square foot of filter surface per hour, which varies from 1 to 8, with cake moisture of 60 to 80 per cent. The capacity for a given sludge depends on the accuracy with which the optimum amount of ferric chloride is fed in conditioning the sludge. The drum is covered with a cloth (as the filter medium) which is usually woolen for acid sludge and cotton for alkaline. Cotton, wool and woven glass cloths for strong solutions, and porous rubber for acid and fatty solutions can be supplied. The filter medium usually is spirally wound with Monel, stainless steel or bright steel wire in Eimco filters. Eimco recently has developed a new type of division strip which permits the elimination of wire winding on standard sewage filters.

About 25 per cent of the drum is submerged in the sludge and vacuum is applied from the point of submergence to the point of discharge, as a rule 20° below the horizontal. In Eimco filters, air pressure is applied to one or more of the drum compartments as they descend toward the scraper, thus loosening the cake from the cloth; this air also cleans the pores of the filter cloth.

A vacuum filter installation consists of a sludge pump or bucket elevator, chemical feeders, sludge conditioning tanks, vacuum filter, vacuum receiving tanks, moisture trap, vacuum pump, filtrate pump, blower, filter cake conveyor and sludge cake hopper. Eimco furnishes all as a complete plant, made entirely in their own works. They recommend the use of acid-proof "Heresite" on the surfaces of all sewage filters and auxiliary equipment as a protection against corrosion.

It is necessary to condition the sludge before filtration to facilitate separation of the solids from the liquid. This is effected by adding chemicals. In most of the latest installations the sludge is elutriated before adding the chemicals, thus reducing the amount of chemicals needed, in some cases by 50 to 70 per cent. Conditioning chemicals used are ferric chloride and lime, or ferric chloride alone, depending on the characteristics of the sludge to be dewatered. Fresh settled and chemically precipitated sludges are best conditioned with lime and ferric chloride. Activated sludge and elutriated digested sludges are usually conditioned with ferric chloride alone. Digested sludges may be conditioned either with ferric chloride alone or with ferric chloride and lime. The amounts of conditioner used average about 1.5 per cent ferric chloride and 10 per cent lime, on a dry solids basis, for plain settled or chemically precipitated sludge; 1.5 per cent ferric chloride and 8 per cent lime for digested sludges; 1 to 3 per cent ferric chloride for elutriated digested solids, and 3 per cent of ferric chloride only for activated sludge. Some cities have found that purchasing ferric chloride in liquid form eliminates troubles experienced with feeding ferric chloride purchased in crystal form and that chemical costs are lower.

The sludge cake removed from the filter commonly drops onto a belt conveyor, which removes it to the incinerator or other desired point.

Sewage plant records should include the weight of sludge cake made each day, and this is most conveniently obtained by weighing it while it is on the conveyor belt. Devices for weighing continuously while the belt is in motion are available. The scale weighs the load continuously as it passes and transmits to a totalizer the instantaneous variations in weights and belt speed period. The totalizer combines and indicates the cumulative result on a dial.

GALE OIL SEPARATOR COMPANY, INC.

52 Vanderbilt Ave., New York, N. Y.

Among the many successful installations of Gale Oil Interceptors and Separators are the two units which have been operating since early in 1942 at the Willow Run Bomber Plant, Ypsilanti, Mich. Herewith is a brief report, with operating data, as furnished by Mr. N. Herda, Superintendent of Sewage and Industrial Waste Treatment at the Willow Run Bomber Plant:

"Due to the excessive amount of oil discharged into the lake, exceeding the 25 p.p.m. requirement of the Michigan Department of Health, it was necessary to install two oil interceptors and separators to receive all waste waters from parking grounds, press rooms, machine shops, hangars, etc. These separators, as furnished by the Gale Oil Separator Co., Inc., were put into operation early in 1942. Their maximum design capacity is 1,000 g.p.m.

"Our experience with the Gale Oil Interceptors and Separators has been highly successful since their installation. Typical analyses are shown in Table I."

TABLE I.—*Results of Analyses of 16-hr. Composite Influent and Effluent Samples taken at Gale Oil Separators, Willow Run Bomber Plant, May 14, 1945 (results in p.p.m.)*

	No. 1 Separator		No. 2 Separator	
	Influent	Effluent	Influent	Effluent
Phenol alkalinity	0.0	0.0	0.0	0.0
Total alkalinity	55.0	38.0	55.0	110.0
Bicarbonates	55.0	38.0	55.0	110.0
Carbonates	0.0	0.0	0.0	0.0
Sulfates	38.9	28.5	55.6	53.5
Chlorides	24.7	24.7	24.7	24.7
Total hardness	180.0	140.0	160.0	280.0
Non-carb. hardness	125.0	102.0	105.0	170.0
Total solids	419.0	250.0	1442.0	408.0
Total suspended solids	183.0	23.0	293.0	24.0
Total dissolved solids	236.0	227.0	1149.0	384.0
Total volatile solids	193.0	80.0	1201.0	138.0
Silica (SiO_2)	12.0	11.0	12.8	11.6
Iron and aluminum (R_2O_3)	10.4	3.6	10.4	2.8
Magnesium	19.9	20.1	8.9	26.3
Calcium	39.2	22.8	49.2	68.6
Oil-Grease-Fats (ether ext.)	3139.0	8.0	1722.0	5.0

GENERAL CHEMICAL COMPANY

40 Rector Street, New York 6, New York

ALUMINUM SULFATE

Yesterday—Today—Tomorrow

YESTERDAY

As early as 1740, sanitarians were experimenting with the use of aluminum sulfate. From 1850 to 1900 there are many references to sewage treatment plants using aluminum sulfate.

More often than not, up to nine other materials were used along with it, such as clay, blood, salt, charcoal and lime. They were supposed to aid in the coagulation process and, in general, to provide the "perfect treatment." Patented processes were numerous.

Many of the "perfect treatments" proved considerably less than perfect and the complicated formulas were discarded. The chemical treatment of sewage suffered because of chemical and mechanical defects. Chemically, the coagulants were overloaded with inert material and some were definitely detrimental to floc formation so that huge doses had to be used. One compound made up of ten materials had only 23 per cent of aluminum sulfate and therefore 4 to 5 times as much had to be fed to reach the coagulant demand of the sewage. The inert components increased the volume of sludge produced and adequate mechanical means were not available for coping with the sludge. Even where clarification was excellent, the lack of good mechanical equipment doomed the treatment.

TODAY

From 1930 to the present time, sanitarians have had an opportunity to evaluate methods of treatment. They have been provided excellent equipment for all types of plants. They know better what to expect from the primary treatment plant, the degree of treatment of which chemical coagulation is capable, and how much B.O.D. and solids reduction can be expected from the secondary and complete treatment plants. Chemical treatment with aluminum sulfate has filled the gap between the 35 per cent reductions of primary treatment and the 90 per cent reductions of complete treatment. Accordingly, during the last 10 to 15 years some three hundred plants have been built to use aluminum sulfate and other sewage coagulants. Aluminum sulfate is "doing a job" in these plants, not only of clarification of the raw sewage, but of speeding sludge drying on sand beds, too. Thousands of tons have been used for coagulating sewage and dewatering sludge in plants all over the country.

TOMORROW

Engineers are looking to the future. Municipalities are looking ahead. New plants must be built and old ones modernized to give higher degrees of treatment. Chemical coagulation will be turned to in order to obtain the 60 to 75 per cent reductions desired. Where streams are seasonally low, engineers are planning on supplementing primary treatment with alum coagulation. The plant that can double its efficiency during low stream conditions by the flick of a switch, is appealing. Chemical treatment has such flexibility. It not only steps up efficiency seasonally at low cost, but will do the same year around most economically.

Trade waste treatment will be carried on at a greater degree than ever in the postwar period. New types of wastes will be encountered, wastes not amenable to biological treatment. Chemicals will adjust such wastes and will treat them so that efficient clarification will be obtained. The possibility of by-product recovery will be closely studied, so that industry may benefit from materials once discarded. Aluminum sulfate plays an important role in the treatment of dairy, laundry, paper, cannery, certain textile, and other wastes and will most certainly be a useful tool in the hands of the chemical and sanitary engineer of tomorrow. As an engineer you should be aware of what aluminum sulfate can do and consider it for your postwar plants.

GENERAL ELECTRIC COMPANY

Bridgeport, Conn.

THE GENERAL ELECTRIC "DISPOSALL"

The Disposall represents an achievement in municipal sanitation practice, second only to the development of the water-carriage system of sewage disposal as a substitute for the backhouse. During the past decade it has demonstrated itself to be a dependable plumbing device which produces a water-carriage waste which readily mixes with the sanitary sewage flow of a community to become a readily transported and easily treated sanitary waste.

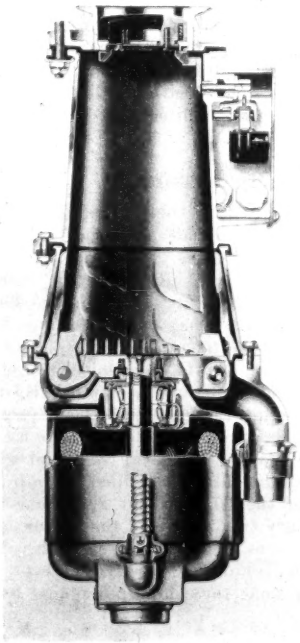
Just as the public sewer replaced the surface collection of sewage solids, after storage in the backhouse, so the Disposall will replace the surface collection of garbage, after storage in the backyard garbage can. There are, after over 10 years of pioneering of this process, some 50,000 Disposalls in use in over 300 communities in the United States.

It is not expected that the Disposall process will immediately replace the time-worn garbage can and present methods of collection and disposal of food-wastes. It will take a generation or more to make the instantaneous discharge of properly ground food-wastes from the home a universal process, yet every public health official will recognize that this elimination of putrefactive garbage from the home is a sanitation development which will raise standards of American living.

THE EQUIPMENT

The Disposall is an electrical grinder that is installed under the kitchen sink, connected to the drain opening of the sink and plumbed into the sink drain line. It is always installed in full compliance with local plumbing regulations. It is free from cross-connection hazards since there is *no* water connection, it obtains water from the sink faucet. Full installation instructions are supplied the plumbing trade.

The unit consists of a sink opening; a storage and grinding compartment; shredding elements; a flywheel and motor assembly and control; a semi-pump and drain outlet for discharging the wastes and water into the usual sink drain trap and piping. A "Safety Twistop" closes the sink opening and starts the grinder when the cover is twisted to the "on" position. A "Flow Interlock," connected to the cold water supply, prevents the unit from



The General Electric Disposall.

running until the proper amount of cold water is flowing from the sink faucet.

The unit is self-scouring and is always clean and fresh-smelling. It operates, less than a minute a day per person in the family, with a use of water that is approximately 1½ gal. per minute. Therefore, the water requirements for disposal of fresh food-wastes, before they become garbage, are approximately 1 gal. per person per day. This is less than 1 per cent of the normal water consumption per capita and, similarly, less than 1 per cent of the per capita sewage flow.

THE BENEFITS OF THE PROCESS

The elimination of putrefactive food-wastes has hygienic benefits, as well as saving of time and inconvenience to the householder. The garbage can is the breeding and feeding place for flies, rodents and stray animals; it produces odors. Since the fly and the rodent are potential spreaders of disease, the elimination of the garbage can by the Disposall should be a means of controlling many of the filth diseases. The disclosure that polio may be a filth disease spread by the fly adds even greater importance to the role of the Disposall in future American communities.

EFFECT OF DISPOSALL ON MUNICIPAL SEWAGE WORKS

Research has demonstrated that properly ground food-wastes are readily carried through sewers and treated at sewage works. If every home used a Disposall, the sewage flow would be increased but 1 per cent in total volume. For many years to come, the number of Disposalls installed in any community will impose little added loading on the treatment plant. For example, in a community of 100,000 population, the use of 100 Disposalls would increase the B.O.D. of the raw sewage ⅛ of 1 per cent and the suspended solids ½ of 1 per cent. The sewage flow of the city would be increased by a total of approximately 500 gal. per day.

GRUENDLER CRUSHER AND PULVERIZER COMPANY

2915–21 N. Market St., St. Louis, Mo.

Sanitary engineers of municipalities have selected Gruendler equipment to eliminate the nuisance of undesirable material and waste products clogging sewage and sludge valves and piping. New patented features make possible uninterrupted flow notwithstanding frequent quantities of prevailing rag stock. The Gruendler Shredder is of the wing hammer design with double-end cutting hammers with sawtooth cutting edges revolving inside a cylindrical sawtooth edge shredder plate at 1,200 to 1,800 r.p.m. Capacities are 500 to 8,000 lbs. per hour. Motors are direct connected, and range from 5 to 70 h.p.

The Gruendler Shredder is outstanding because of its patented features such as the Non Clogging Grate Bars, Safety Tramp Iron Catchers and Improved Water Spray Flushers.

The Gruendler Sewage Screening Shredder also makes an ideal connection with an incinerator—by grinding, mixing, and preparation in one operation, it prepares product for most efficient combustion and proper feeding.

Gruendler Shredders are dependable and of sturdy construction with sealed bearings to withstand continuous operation. The safety feature of the Gruendler Tramp Iron Catcher is noteworthy, since foreign matter such as cans or metal, which is ungrindable, is easily removed through the access door provided. These shredders are built

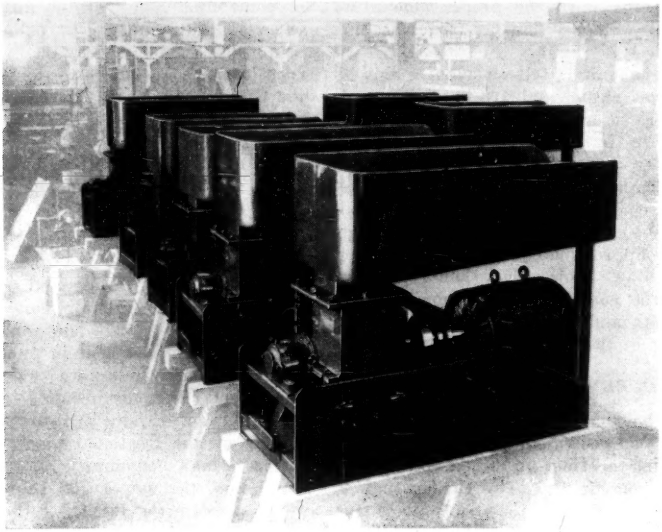


FIG. 1.—Lineup of several Gruendler Garbage Shredder Units ready for crates and shipment to the U. S. Navy. For installation on battleships and merchant marine; hundreds of these shredders were employed in the war effort.

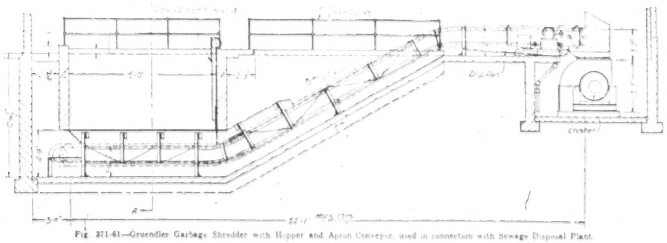


FIG. 371-61—Gruendler Garbage Shredder with Hopper and Apron Conveyor, used in connection with Sewage Disposal Plant.

FIG. 2.—Diagram No. 371-61 showing Gruendler Garbage Shredder with hopper and apron conveyor, used in connection with Sewage Disposal Plant.

in many sizes and can be fitted in most difficult plant arrangements, taking a minimum of space, and the many designs meet sewage works requirements for higher efficiency. The grinding of sludge to uniform sizes for commercial fertilizer is another operation performed by Gruendler's Hammer-Type Cake Breakers.

Hundreds of Gruendler Shredders have been selected by the U. S. Navy as standard equipment on battleships and merchant vessels.

Blue prints and sewage works layouts, together with specifications, will be gladly furnished municipal engineers, plant superintendents or plant designers by the Gruendler Company. Address Plant and General Offices in St. Louis 6, Mo.

HARDINGE COMPANY, INC.

York, Pennsylvania

NEW EFFLUENT FILTER

In addition to the regular clarifiers, which are offered for sludge collecting in both circular and rectangular settling tanks, the Hardinge Company now offers an Automatic Backwash Rapid Sand Filter as an effluent filter for the removal of suspended solids from liquid wastes, not readily removed by sedimentation methods. Although developed in 1940, a number of installations have been made in sewage treatment plants and for the treatment of industrial wastes, handling the effluent or overflows from sedimentation units. The filter consists of a specially compartmented sand bed with underdrains, together with a suitable backwash cleaning mechanism, traveling on tracks on the sidewalls of the filter tank and actuated electrically at predetermined head differentials. It can be supplied in sizes varying from 3 ft. to 16 ft. in width and length to suit local conditions, up to 100 ft. in length.

The filter bed is divided into a series of narrow compartments, each connected to a separate effluent and backwash port. The filter bed is usually 6 in. deep and is carried on supporting floor plates or metal screens.

The cleaning mechanism consists of a motor driven carriage, which operates periodically back and forth over the length of the filter bed. The carriage is equipped with two pumps, one a backwash pump, which takes the filtrate from the effluent channel and pumps it back through the sand bed; the other a wash water pump for removing the dirty wash water, which is retained inside a hood over the compartment being washed.

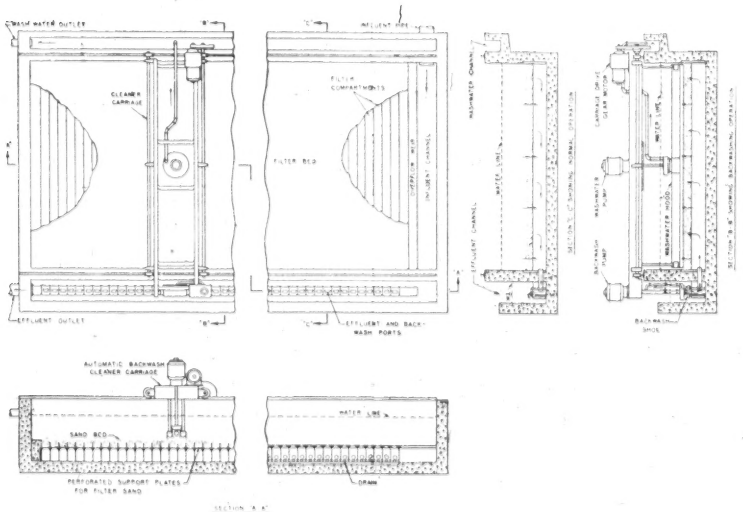


FIG. 1.—The Hardinge Automatic Backwash Rapid Sand Filter.

In the operation of the filter the feed flows into the filter tank through the weir ports or over an influent weir. The liquid passes through the sand bed into the bottom chamber of the compartment and out through the individual ports, into the effluent channel. As suspended matter gathers on the surface of the sand filter bed, the filtering rate is decreased and the head in the filter tank begins to build up. As a predetermined level is reached, an electrical contact starts the carriage and the washing pump. The backwash valve or shoe, attached to the moving carriage, rides over the various effluent ports. As each connection is made, the backwash pump delivers clean water from the effluent channel through the ports, into the lower section of the compartment and upward through the sand filter bed. The wash water is collected inside the cleaner hood, located directly above the compartment being washed, and pumped from it to the wash water launder.

In the sewage treatment field, the use of the filter is attractive on sewage projects where a high removal of suspended solids is desirable but where the high removal of B.O.D. may not be necessary. It can in such cases be advantageously used, following the primary clarifier, to give an overall removal of 75 per cent to 80 per cent of the suspended solids. If chemicals are added, a suspended solids removal of 90 per cent or better can be effected. It may also be used to advantage on the effluent from final settling tanks in trickling filter and activated sludge plants, where a high clarity of the final effluent is required.

At this writing, several units are operating in sewage treatment plants and a number of units have been installed and are operating in the paper industry, handling paper mill waste water. In most cases the fibre and filler in the waste water are recovered and re-used, while the water is sufficiently free for re-use as process water.

Figure 1 shows the general design of the filter and its operation.

INFILCO INC.

325 W. 25th Place, Chicago 16, Ill.

ACCELO-FILTERS, ACCELO BIOX PROCESS, ACTIVATORS, CLARIFIERS, SKIMMERS, ROTARY DISTRIBUTORS, AUTOMATIC DOSING SIPHONS, AUTOMATIC PROPORTIONERS, ACCELATORS, CHEMICAL FEEDERS, MIXERS, GRIDUCTORS, COAGULATORS, VENTURI TUBES AND CONTROLLERS

NEW DEVELOPMENTS

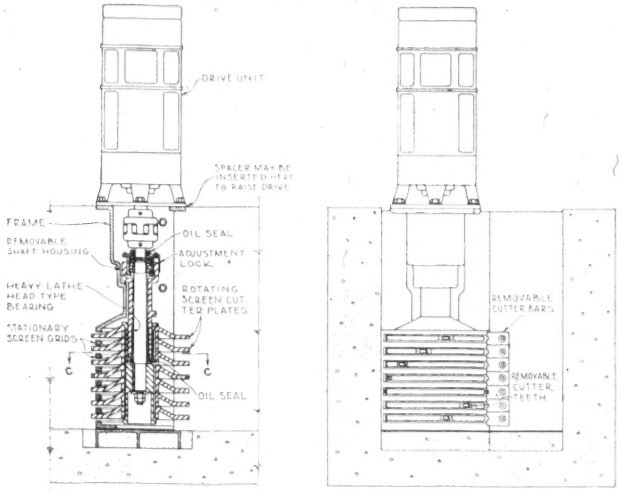
Design and development of new equipment and improvements to present equipment are progressing more satisfactorily as war work diminishes. Research in industrial waste treatment has been given more attention in our chemical laboratory during recent months. Adaptation of present mechanical equipment to the treatment of these wastes has prompted engineering study and design with resultant improvements that will also apply in the treatment of domestic sewage.

GRIT REMOVAL MECHANISM

Further progress is being made on our new grit removal mechanism and it is expected that this equipment will be available by the end of the war with Japan.

GRIDUCTOR

Several improvements to the Griductor (Figure 1) have been added which



GRIDUCTOR

Fig. 1. The Infilco Griductor.

will improve the efficiency of this screen and cutter mechanism. The Griductor comprises a semi-circular stationary screen grid with slots of sufficient width to permit mounting a series of rotatable circular screen cutter plates or discs in such a manner that the assemblies form screen slots both above and below each cutter plate. The discs extend outward beyond the face of the grid and form in effect a coarse screen. As these screen discs with the cutter teeth are rotated, the intercepted screenings are dislodged from the screen element and moved to an adjacent stationary cutting bar or comb. Reduction of the size of the solids is accomplished by the engagement of the cutting comb with the teeth fixed to the edge faces of the rotating screen cutter plate—a shearing action is thus provided. The teeth are staggered on the cutter plate in such a manner that only one tooth at a time can transmit a cutting load.

Each tooth is held in place on the disc by a tooth holder clamp which is recessed deeply into the disc so that the cutting load stress is transmitted to a substantial area of the plate. The tooth holder permits radial adjustment of the cutter tooth so that correct cutting clearance may be maintained. See illustration.

The cutting edges of both the teeth and the stationary combs are made of the most durable material available for service of this nature. Both the teeth and the cutter combs may be removed easily for renewal purposes. As both ends of each tooth are sharpened and ground to proper shape, a complete extra set of teeth is available with each machine. Additional cutter bars may also be had if desired.

The rotating assembly of screen cutter plates is driven by a vertical motorized reducer through a flexible coupling. The motor is suitable for outdoor, all-weather service. An anti-

friction type bearing designed to take both vertical thrust and horizontal alignment loads is placed at the upper end of the removable shaft housing which is fixed within the main frame. A heavy lathe head type bearing is provided at the lower end of the vertical shaft to take alignment loads caused by the shock or impact of the cutting action. The rotating screen cutter plates are mounted on and keyed to the removable housing and vertical shaft so that the entire assembly may be removed by disconnecting the flexible coupling and removing four cap screws.

In the standard assembly of the Griductor the unit is mounted on a base plate which in turn rests on the bottom of the screen channel and the vertical motorized reducer is mounted on the stationary grid. However, when necessary the Griductor will be furnished with an extended shaft so that the motorized reducer may be mounted on a floor or other structural support any reasonable distance above the channel bottom. It is also possible to position the motorized reducer above the Griductor as desired by inserting a flanged spacer piece between the top of the grid frame and the base of the reducer.

Sewage solids too large to pass through the slots between the stationary screen grid and the rotatable screen cutter plates are intercepted and intermittently subjected to the shearing and cutting action of the cutter teeth until they are reduced to pieces sufficiently small in size to pass through the screen slots.

Griductors may be obtained for either right hand or left hand operation. This permits the use of duplicate units in individual channels for standby and peak load services. Dual units may be installed also in a single channel where required by high sewage flow rates or by the screening and cutting demand of an abnormal sewage or industrial waste.

The Griductor motor control may be either manual or automatic. If automatic intermittent service is desired, the starter may be operated either (1) by an adjustable timing device or (2) by actuating mechanism responsible to the actual screening and cutting demand as measured by a head differential.

Irrespective of the type of control used the Griductor motor will be started and stopped independently of the rate of sewage flow.

DIRECT RECIRCULATION AND ACCELERATED BIOLOGICAL OXIDATION

The benefits and advantages of the immediate direct return of aerobic organisms to an aerobic process continues to be demonstrated by several Accelo-Filter plants in service. The direct recirculation feature of this system also provides a cost advantage through the use of smaller sedimentation tanks.

The Accelo Biox demonstration at Columbia, Mo., was interrupted by the sudden death on February 4 of our service engineer Mr. John Wesley. Continuation of this demonstration installation has been delayed due to the manpower shortage. It is planned to continue the work when circumstances permit. Results obtained to date have proven the economy and efficiency of this system and have borne out the pilot plant data obtained by Mr. J. A. Logan.

CONCRETE DOME SUPPORTED DIGESTERS

Infilco Digester mechanisms arranged for reinforced concrete dome cover support either in the vortex circulator type or the sludge scraper-scum breaker type, for either single stage or two stage operation are now available.

LAKESIDE ENGINEERING CORPORATION

222 West Adams St., Chicago, Ill.

AERO-FILTER

The Lakeside Engineering Corporation will have a reprint covering results produced by single and two stage Aero-filters ready to distribute before the end of 1945. This reprint shows the effects of various plant conditions upon results. For example, a graph shows the effects of different recirculation ratios through the filter upon single stage results. Another graph discloses that different divisions of the rock between the two filters of a two stage plant give different results.

Disc distributors are recommended for filters 25 ft. in diameter or less, but they may be used on larger filters up to and including those 34 ft. in diameter. For larger filters, with average capacities up to 4,000 g.p.m., multiple arm distributors are used. Distributors are supplied for any filter diameter provided the average flow does not exceed approximately 4,000 g.p.m.

Lakeside's recently improved method of connecting the nozzle to the distributor arms and an improved nozzle cover make the units almost 100 per cent proof against clogging trouble. Therefore, a minimum of attention provides maximum distributor efficiencies throughout the 24 hours of the day.

The Aero-filter provides a relatively low over all plant cost because it requires much less recirculation than other types of high capacity filters to produce equal B.O.D. reductions.

CLARIFILTER

This is a combination contact filter and clarifier embodying some very interesting features. A complete two stage plant can be constructed through the use of three tanks. The design insures maximum efficiency with minimum cost. It is the only contact filter on the market that insures uniform distribution of the sewage over the contact surfaces.

A Clarifilter consists of a tank structure, normally built of reinforced concrete, within which a skirt of aluminum sheets is placed concentric to the tank wall and supported on it. The skirt is placed 3 or 4 ft. from the wall, thus forming a race between it and the wall. By means of a supporting structure, vertical plates are placed radially around this race, being spaced approximately 1.5 in. from center to center. Air diffusers are located below the plates, being suspended from the top of the skirt in a manner which makes it possible to remove them in sections without entering the tank itself, without emptying the tank, or without removing the plates.

The incoming sewage is distributed uniformly at the top of the plates throughout the entire length of the race, since it is fed over a weir from a trough built along the top of the tank wall. Thus, one of the chief difficulties experienced with contact filters—that of distributing the sewage uniformly over the contact surfaces—has been overcome.

The sewage passes downward between the plates against the upward current of diffused air until it reaches the bottom of the skirt. The liquid then passes under the skirt and rises in the main section of the settling compartment to a collecting trough which is concentric to the tank wall. This trough is so constructed that its two weirs have a total length approximately equal to the circumference of the skirt. The arms of the scraper mechanism in the bottom of the tank extend under the contact plates to the tank wall. The mechanism continually scrapes the sludge, deposited from the

plates, to the center well from which it is removed several times each hour.

SPIRAFLO CLARIFIER

The Spiraflo clarifier is in some respects similar to the Clarifilter. The race between the tank wall and skirt is much narrower, however, and no contact plates are used. The incoming sewage enters the Spiraflo clarifier from a head box through an orifice at the top surface of the race and flows around the race in a downward spiraling motion. Before the liquid can enter the main section of the settling compartment it must flow downward for a distance of 7 to 8 ft. at a rate of about 0.6 ft. per minute. Such a slow downward velocity insures a good separation of floating oil, grease and other materials (the primary clarifier scum), which is carried around the race to a baffle where it is drawn off periodically.

The liquid passes under the bottom of the skirt and then rises spirally and slowly in the central portion of the clarifier, through the sludge blanket. It finally passes over the two weirs on the centrally located effluent trough.

The Spiraflo clarifier offers three distinct advantages, namely:

1. Better skimming, oil and grease removal than is usually obtained by clarifiers.
2. The two weirs on the outlet trough are approximately the same length as the inverted weir at the bottom of the skirt; in other words, the inlet and outlet weir velocities are the same—both very low.
3. Since all of the liquid must pass close to the bottom of the tank, the actual detention time approaches the designed time much closer than is usually the case. In other words, there can be no short circuiting.

LAMOTTE CHEMICAL PRODUCTS COMPANY

Towson 4, Maryland

NEW SERIES LAMOTTE CHLORINE COMPARATORS

The Research Department of the LaMotte Chemical Products Company of Towson, Baltimore, Md., has completed a thorough survey of the improved application of chlorine in the form of free chlorine, hypochlorites and chloramines as sterilizing agents in the treatment of water for municipal supply, for sewage and a host of industrial uses. As a result of these studies a complete new line of LaMotte Chlorine Control Units have been made available paralleling the recent advances in the more effective chlorination procedures. The latest recommendations of the Committee on Control of Chlorination of the American Water Works Association have been carefully followed, and a new series of standards have been prepared of a size interchangeable with the regular LaMotte pH color standards. An additional new development is the ortho tolidine-arsenite test, which makes it possible to measure separately chloramine and active chlorine and, furthermore, it is possible to estimate the error that is caused by other interfering substances. A pamphlet describing the ortho tolidine-arsenite test is available and should be of interest to all operators.

NEW LAMOTTE CHLORINE TESTING OUTFITS

1. LaMotte Chlorine Colorimeter.—For low chlorine concentrations, 0.02 to 0.3 p.p.m. Standards are prepared in special sealed Nessler Tubes, with polished tops and bottoms.

2. LaMotte Chlorine Block Comparator (Standard Model).

LAMOTTE CHLORINE BLOCK COMPARATOR

(Standard Model)

(For Medium Chlorine Concentrations 0.1 to 1.0 p.p.m.)

This is a modification of the LaMotte-Enslow Chlorine Comparator that was originally developed with the cooperation of Mr. L. H. Enslow. The arrangement of tubes eliminates any error due to color or turbidity of the sample, such as may be encountered in raw water, sewage and industrial wastes. The set consists of 10 chlorine color standards, values 0.1, 0.2, 0.3, 0.4, 0.5, 0.6, 0.7, 0.8, 0.9 and 1.0 p.p.m. chlorine; 1 ampoule of distilled water; 3–10 ml. test tubes; 1–0.5 ml. pipette with nipple and 50 ml. of ortho-tolidine reagent. This equipment is contained in a polished wooden case, the top of which serves as a comparator for color readings.

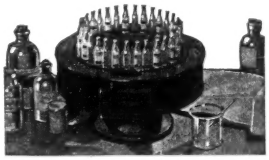
3. LaMotte H C Chlorine Block Comparator—For high chlorine concentrations, 1.0 to 10.0 p.p.m., and by dilution to 200 p.p.m. and above.

4. LaMotte Wide Range Chlorine Comparator—Range 0.1 to 10.0 p.p.m. and by dilution to 200 p.p.m. and above.

5. LaMotte Roulette Chlorine Comparator.

LAMOTTE ROULETTE CHLORINE COMPARATOR

(A Wide Range Unit)



Range 0.1 to 10.0 p.p.m., and by dilution to 200 p.p.m. and above. Designed as a permanent installation in the control of chlorine dosage. It contains an internal daylight reading arrangement, and all standards are in the revolving drum, permitting the operator to obtain readings in a minimum of time and under uniform light conditions.

6. Combination pH and Chlorine Outfits—Special new combination outfits have been designed to contain any selected range of pH and chlorine standards, compactly arranged in a single case. The chlorine color standards are of a size interchangeable with the regular (15 mm.) LaMotte pH color standards.

MABBS HYDRAULIC PACKING COMPANY

431 South Dearborn St., Chicago, Ill.

PACKING SLUDGE AND SEWAGE PUMPS

The question of packing frequently is not given the consideration it deserves, either by the manufacturer of pumping equipment or the operating engineer. If the damage to rods, plungers and shafts caused by certain packings was charged against the packing, it would make its cost prohibitive. Yet many engineers insist on using inferior packings simply because the first cost is less. It is common knowledge that most packings used in sludge and sew-

age pumps become hard after a short period in service. Then is when the trouble starts. Particles of grit in the sewage handled imbed themselves on the hard packing surface and are held there as if in a vice, and the cutting and scoring of the sleeves begins. In a comparatively short time these expensive parts must be replaced.

The packing desired is one that will not become hard or glazed. Such a packing is found in braided Rawhide,

and this packing has the additional advantage that when it is saturated, it is as slippery as an eel and practically frictionless, thereby greatly reducing the friction load.

Rawhide Packing, if kept wet, always remains soft in service; the particles of grit either wash away or work back into the body of the packing, and so prevent the cutting and scoring of the metal surfaces.

These claims are made, of course, only for the genuine Mabbs Rawhide Packing manufactured by the originators of Rawhide Packing, The Mabbs Hydraulic Packing Company of Chicago.

A point to bear in mind when first cost is considered is that Mabbs Rawhide Packing weighs only two-thirds as much as flax packing and therefore costs no more per pound than flax.

The Mabbs Hydraulic Packing Company will be glad to assist operating engineers in any of their packing problems.

MERCO NORDSTROM VALVE COMPANY

Subsidiary of

PITTSBURGH EQUITABLE METER COMPANY

Pittsburgh, Pennsylvania

NORDSTROM LUBRICATED PLUG VALVES

Nordstrom Valves are well adapted to the requirements of Sanitation Departments for use in sewage disposal plants because of their leak-resistant, non-sticking and positive shut-off construction. Made in a wide range of sizes and for various pressures.

Lubricant system in Nordstrom Valves.

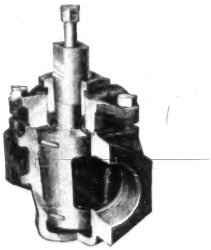
"SEALDPORT" LUBRICATION

The "Sealdport" method of valve lubrication forces "Nordcoseal" Lubricant under high pressure between the plug and body, making the valve leak-resistant and freeing the plug to assure easy operation. Simply turning a screw at the top of the valve completely covers both seat and plug surfaces with a film of lubricant.

Lubricant grooves in the valve body and plug are so arranged that the lubricant cannot be blown from the valve by the fluid or pressure in the

line. The Nordstrom method of "Sealdport" lubrication has made practical the use of plug cock valves as large as 30 inches in size and assures the most satisfactory service for sewage disposal plants.

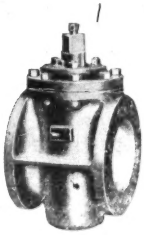
In the phantom view, shown above, the lubricant grooves on the plug and in the valve body may be clearly seen. These grooves form an interconnecting system which conducts the lubricant to the lower end of the plug in either open or closed positions of the valve.



Cut-away view Nordstrom Valve.

The principle of high pressure "Sealdport" valve lubrication may be easily traced through the entire valve in the phantom view.

At right is shown plug assembled within valve body and with the especially designed gland and yoke in place.



Emco Nordstrom Valve with standard face-to-face dimensions.

Should neglect to lubricate occur, valve will remain tightly seated because all unbalanced pressure is in a downward direction and can be readily freed by inserting a stick of Nordstrom Lubricant and turning down the screw.

EMCO–NORDSTROM LUBRICATED PLUG VALVES

These valves have standard gate valve face-to-face dimensions and embody all the advantages inherent to the general Nordstrom line, including the patented "Sealdport" method of lubrication and plug lifting features that make operation easy and positive at all times. It is now economical to replace valves of other types with these lubricated plug valves since they can be installed without altering existing pipe dimensions.

MINE SAFETY APPLIANCES COMPANY

Braddock, Thomas and Meade Sts., Pittsburgh 8, Pennsylvania

SAFETY FOR THE SEWAGE PLANT WORKER

For many years, the sewage treatment industry has looked to Mine Safety Appliances Company, as the world's largest manufacturer of safety equipment, for its protective equipment—everything from respiratory protection to safety clothing and first aid supplies. Here are a few of the more important M.S.A. products which have been vital in the modern sewage works safety program:

M.S.A. GAS INSTRUMENTS

Among the many M.S.A. instruments for protection against combustible gases is the M.S.A. Combustible Gas Alarm, Explosion-Proof Type EX-S. Accurate detection and indication of combustible gases and vapors in air is provided for modern sewage works practice with this precision gas instrument. The alarm gives a visible and audible warning when the concen-

tration exceeds a predetermined limit. Completely explosion-proof in operation, the instrument can be located safely in hazardous areas. It can also be interconnected with ventilation controls as well as with remote recording potentiometers.

The M.S.A. Explosion-Proof Combustible Gas Alarm is available in a special panel assembly, or in a compact design for wall mounting. It operates on 110-volt, 60-cycle, single-phase alternating current.

M.S.A. RESPIRATORY PROTECTION

The M.S.A. All-Service Gas Mask provides dependable respiratory safety wherever toxic gases are encountered in sewage works operations, singly or combinations (including carbon monoxide), as long as sufficient oxygen is present in the air to support life. U. S. Bureau of Mines-approved, the All-Service Mask features the snug-fitting, gas-tight, comfortable All-Vision Facepiece with large-area lenses affording unobstructed vision. The light-weight harness of the mask permits easy working freedom. The long-lived All-Service Canister is easily replaceable.

For specialized protection against chlorine hazards, wherever this gas is handled or produced, the M.S.A. Chlorine Mask is ideal. This mask also features the All-Vision Facepiece and quickly-replaceable canister.

M.S.A. RUBBER PROTECTION SUIT

Complete body and respiratory protection is furnished for the wearer by the new M.S.A. Rubber Protection Suit worn in conjunction with the M.S.A. Combination Hose Mask. The suit is completely liquid and gas-proof, consisting of a suit and hood, available separately, made of heavily rubberized, black, double-texture material, hand doubled, stitched, cemented and strapped at all seams, and then vulcanized to assure waterproofness. The gloves and boots are permanently attached to the suit, which is available in small, medium and large sizes.

The M.S.A. Combination Hose Mask, worn with the Rubber Protection Suit to complete all-around protection, furnishes fresh outside air to the wearer, supplied by a hand-operated blower through as much as 150 feet of hose. The M.S.A. Hose Mask is equipped with the All-Vision Facepiece, double over-the-shoulder inhalation tubes, and hand-operated blower.

OTHER PROTECTIVE EQUIPMENT

Descriptive bulletins on any of these M.S.A. safety products will be gladly sent upon request, together with any others desired, including further details on M.S.A. First Aid Kits and material; M.S.A. Explosimeters, compact, portable combustible gas indicators requiring only one-hand operation; M.S.A. Hydrogen Sulfide Detectors; and M.S.A. Protective Clothing.

Copies of these bulletins may be secured by writing to Mine Safety Appliances Company, Braddock, Thomas & Meade Streets, Pittsburgh 8, Penna.

MORSE BOULGER DESTRUCTOR CO.

205-D East 42nd Street, New York 17, New York

ENGINEERS AND CONTRACTORS FOR WASTE DISPOSAL PLANTS, SEWAGE SLUDGE DRYING AND INCINERATION

NEW POSTWAR LINE FOR MORSE BOULGER

For over 50 years, the Morse Boulger Destructor Company has been engaged in the design and construction of incineration plants for the disposal of combustible wastes. Incineration plants in daily operation range from home

units to plants for large municipalities.

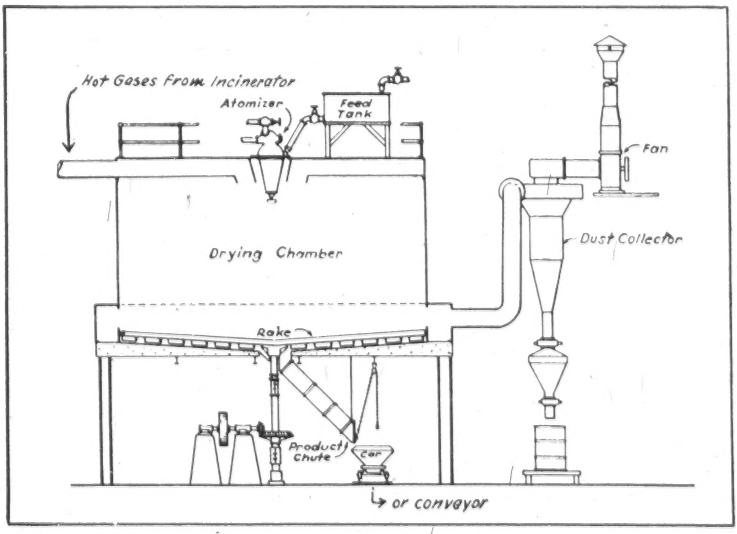
In the sewage works field, Morse Boulger Destructor units for the disposal of screenings have been in operation for over fifteen years in a number of municipalities. A considerable amount of investigation and research has also been carried on in the development of plants for the drying and burning of sludge. Simplicity, flexibility, low operation costs and a minimum of maintenance were considered as being essential characteristics of drying and incineration equipment for sewage treatment plants.

We are now pleased to announce that arrangements have been completed with the Instant Drying Corporation for the exclusive sale and erection of their spray drying systems in the disposal of industrial and sewage sludges.

In the Instant Dryer, sludge of any moisture content may be fed to an atomizer unit located in the top of a drying chamber or tower. The atomizer unit consists of a specially designed bowl rotating at high speed. Hot gases are introduced around the atomizer bowl and the resulting cooler gases and steam are withdrawn from the base of the tower around its circumference. The sludge, thrown from the bowl at high velocity, is separated into individual particles of water and moist solids. The hot gases instantly evaporate the water and, as the solid particles drop to the base of the tower, they are dried to any desired moisture content. The dried solids are removed from the base of the tower for incineration or for use as fertilizer.

Since the speed of the revolving bowl, and the temperature and volume of the hot gases are controllable, great flexibility of operation is obtainable. It should also be noted that the solids in their wet stage are exposed to the hottest gases, and in the dried stage to the cooler gases, with the result that no odors are produced.

When the dried sludge is to be incinerated, it will normally be burned in suspension in the incineration chamber by use of burners of the type used



for pulverized coal. Hot gases from the incinerator are normally used to supply the heat to the drying chamber referred to above. For sludges of high moisture content, or where the sludge is not to be incinerated, the auxiliary fuel may be coal, gas or oil.

This system has been in use for drying and burning sludge in the sewage treatment plant of a New Jersey municipality for the last ten years. Digested sludge is conditioned by alum treatment and flotation, so that the sludge is normally of about 85 per cent moisture content when pumped into the dryer. The records of this plant attest to the flexibility and economy of operation, and to the low cost and ease of maintenance, which assure almost 100 per cent availability of the equipment for operation.

The plant now in operation was designed for an evaporation of 4,200 lbs. of water per hour. Individual units may be designed for evaporation over a wide range, and by use of multiple units, sludge disposal can be handled for sewage treatment plants of any capacity.

NICHOLS ENGINEERING AND RESEARCH CORP.

60 Wall Tower, New York, N. Y.

The Nichols Engineering and Research Corporation has continued the development of equipment for the disposal of sewage sludge, screenings, grit and scum, as well as garbage, rubbish and other municipal wastes.

During the past few months, two new Nichols Herreshoff sewage sludge incinerator installations were placed in service. After over ten years operation of the first Nichols Herreshoff sludge incinerator unit, which was placed in operation in 1934, the growth of the city of Dearborn, Mich., necessitated the installation of a second unit, this being a 16-ft. diameter, 7-hearth incinerator.

An 8-hearth Nichols Herreshoff incinerator, 16 ft. 9 in. in diameter, is being used at the new sewage treatment plant of the city of East Chicago, Indiana. This sludge is from a biochemical treatment process.

The incineration of liquid sludge containing 88–90 per cent water has been continued both at the Asland, Ohio, and Piqua, Ohio, sewage treatment plants with very satisfactory results. Undigested, unfiltered liquid sludge is fed by bucket elevator directly into the Nichols Herreshoff multiple hearth incinerator.

The great simplification in sludge disposal operations and savings in chemicals, maintenance, etc., by incinerating liquid sludges without any mechanical dewatering, unquestionably has wide application.

The Nichols Monohearth garbage and refuse incinerator has met with widespread and enthusiastic acceptance by engineers and municipal officials who have investigated its advantages. This incinerator incorporates automatic, mechanical stoking. It is a circular furnace, the vertical cylindrical steel shell is lined with firebrick and insulation. Directly in the center under the charging opening, there is a slowly revolving cone to which is attached tangential arms. Both cone and arms have numerous holes, through which combustion air, under pressure, is admitted. Immediately surrounding the area covered by the cone and arms, there is a solid cast hearth and between this hearth and the walls there is a substantially continuous annular ring of dumping grates.

The cone and arms perform several functions. They prevent a thick, impervious layer of material from building up under the charging opening.

Duplicate 14 ft. 3 in. diameter, 6-hearth Nichols Herreshoff incinerators at the Cleveland Westerley sewage treatment plant.

They permit preheated or atmospheric air to be blown through the mass of material in such a manner that the air is uniformly distributed. They serve to stoke gently the material from underneath, the rotation of the arms causing the material to be raised as the arms pass beneath. They also stoke the material, cans and ashes out onto the annular grates, where final burning takes place. The ash is, therefore, mechanically pushed onto the dumping areas of the grates. The revolving cone and arms, likewise, prevent the formation of blow holes or bare spots on the grate, thus resulting in much more efficient use of the air which passes up through the grates.

During the past year we have designed and constructed several new Monohearth installations, including a 100-ton capacity plant for the town of Tonawanda, New York, two additions to the refuse incineration plant at the city of Detroit, totaling 350 tons capacity, and one 120-ton unit for the city of Jacksonville, Florida. Some other installations are under construction, including a 225-ton capacity plant for the Washington Suburban Sanitary District, and including the conversion of existing incinerator units of the old conventional, manually stoked types.

We are currently engaged in the design and construction of a combined unit in which combustible refuse and garbage will be burned in a Monohearth unit. Over this will be located a sludge drying hearth incorporating mechanical rabbling, similar to the well-known Nichols Herreshoff system. Sludge containing about 75 per cent moisture will be dried on this upper hearth by a portion of the waste hot gases from the Monohearth refuse incinerator, and the dried sludge will discharge onto the burning material in the center of the Monohearth.

OMEGA MACHINE CO.

(Division of Builders Iron Foundry)

85 Codding St., Providence 1, R. I.

RUGGED, DEPENDABLE, VOLUMETRIC FEEDER

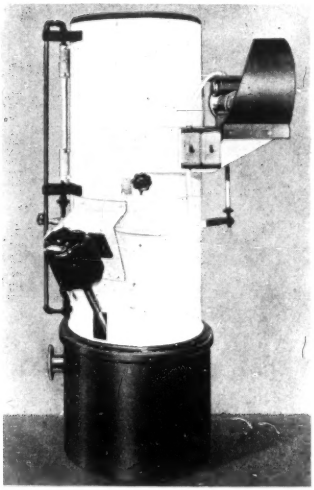


FIG. 1.—No. 3 Universal Feeder with lead-lined mixing chamber.

The Omega Universal Feeder is designed to give unfailing service with a minimum of attention. Strings, lumps and trash which clog most feeders pass right on through the Universal. Capacity range of 40 to 1 is adjustable by easily accessible micrometer screw. The machine is entirely enclosed to make the feeding operation dustless . . . Omega dust removers are available to prevent all dust when filling the hopper. Mounting the feeder on scales is optional; it provides a quick accurate method for keeping an exact check of feeding rate and amount of chemical used. The No. 3 Omega Feeder, with lead-lined mixing chamber, has a ¼ h.p. motor-driven stainless steel agitator for dissolving ferric sulfate up to 100 lbs. per hr. Water is metered by a Rotameter; separate valves are used to regulate and to shut off the water supply. The oscillating, non-clogging throat, producing effective agitation at the feeder outlet, makes the Omega Feeder unusually accurate whether handling dry material in lumps or fine powder. Write for Bulletin.

PRECISION FEEDER FOR LIQUIDS —WITHOUT VALVES, DIAPHRAGM OR PUMP

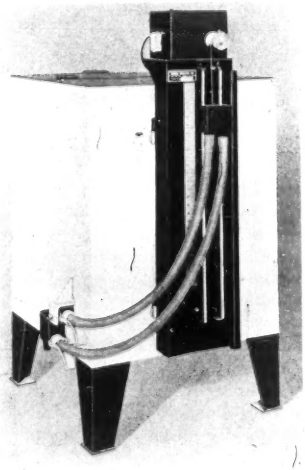


FIG. 2.—The Omega Precision Feeder, for liquids.

The operating principle of the Omega Precision Feeder is simplicity itself. The open end of a hose, connected near the bottom of a chemical tank, is steadily lowered, thereby lowering the level of the liquid in the tank correspondingly—a true volumetric measurement is obtained by

thus controlling the delivery of the liquid. If the hose is lowered 1 in. per hr., the level in the tank will be lowered 1 in. also. The tank has a uniform cross section, and the lowering of the hose is controlled by a synchronous electric motor, 8-day clock or by direct drive from a water meter. Feeding in proportion to flow can be easily arranged. Standard tank sizes are 25 to 200 gals., with feeding range of 100 to 1 from 1/25 to 200 gals. per hr. Nothing to get out of order. Bulletin on request.

PACIFIC FLUSH-TANK COMPANY

4241 Ravenswood Ave., Chicago 13, Ill.

P.F.T. COMBINED DIGESTER HEATER AND HEAT EXCHANGER

The P.F.T. combined digester heater and heat exchanger has been developed to overcome the disadvantages of the normally used method of heating sludge digestion tanks. Up until the present time sludge digestion tanks have been maintained at proper digestion temperatures by means of gas fired heaters or boilers through which water is circulated and then passed through a series of coils immersed in the digesting mass in the digestion tank giving up its heat by transfer to the tank contents. With this system unless the temperature of the circulating water is carefully controlled at below 140° F., the sludge in contact with the coil in the digestion tank is scorched or burned and builds up on the coil. The crust of sludge thus formed acts as insulation and interferes with the proper transfer of heat from the circulated water in the coil to the sludge in the tank. When this building up of material progresses to the point where the tank is not receiving sufficient heat from the circulating water it is necessary to dewater the tank, disrupting the digestion process to knock the scale or crust from the coils.

In addition, it has been found that the inaccessible coils in a digestion tank are a constant source of trouble due to breakage and other difficulties which require removal of the tank from service to make the laborious and expensive repairs. The dewatering of tank contents not only requires a considerable amount of time, but also interrupts the digestion which might present operating problems for a considerable period after the tank is returned to service.

The new P.F.T. combined digester heater and heat exchanger (Figure 1)

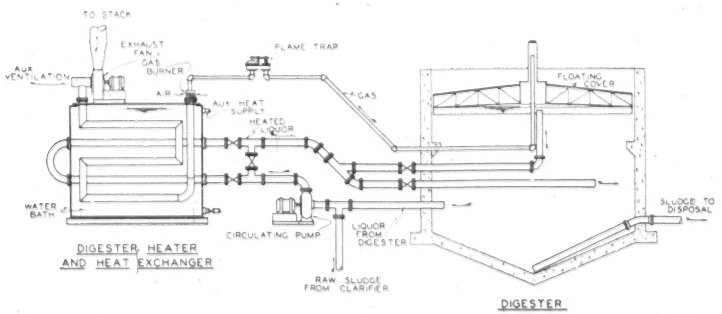


FIG. 1.—Piping arrangement and flow diagram illustrating operation of the new P.F.T. Combination Digester Heater and Heat Exchanger.

provides an accessible means of heating material either circulated from the digestion tank or raw sludge passed into the digestion tank, providing more efficient heat exchange and greater thermal efficiency in the unit. This is due to the fact that the circulated material is passed at a higher velocity through the heating coils, allowing higher temperatures to be carried in the water bath without caking of the material on the inside of the circulating coil.

The unit is so designed that the return bends can be easily removed and the coils cleaned on the inside through which the circulated material from the digester is carried. Such periodic cleaning of the inside of the coils, requiring a minimum of time and labor, makes it possible to keep the heat exchanger at peak efficiency at all times without disturbing the contents of the digestion tank, and during the short interval required for such cleaning operation the temperature of the digestion tank will not drop appreciably.

The outside of the coils through which the material is circulated is in contact with a water bath which is not changed, with the result that there is no caking of material on the outside of the coils.

GENERAL DESCRIPTION

The P.F.T. combined heater and heat exchanger consists of an insulated steel basin through which coils are carried for the circulation of material to be heated. Also contained in the same water bath are immersion type fire tubes in which the combustion of gas takes place. The gases thus burned impart the heat to the water bath and thus to the circulated material in the heater tubes. The immersion fire tubes are of sufficient length to give thermal efficiency of the system of approximately 80 per cent at the normal design rating.

The immersion fire tubes are so arranged that they can be easily removed from the basin for inspection. Also, an inspection port is provided at the end of the first horizontal run of the fire tube for observing the length and nature of the flame during operation of the unit.

The immersion type fire tubes are fired by means of a specially designed combustion chamber provided with adjustable air shutters and furnished with baffles for adequate and proper mixing of air and sludge gas. The proper quantity of air for combustion is provided by an exhaust type fan at the outlet of the immersion coil, exhausting the air and products of combustion to the stack. Auxiliary air inlet and damper is provided on the fan.

SAFETY CONTROLS

Complete and positive safety of both main gas supply and pilot is provided by means of Wheelco "Flameotrol" safety control equipment, approved by Factory Mutual Laboratories and Underwriters Laboratories, which operates on the electrical conductivity of the flame principle and consists of a self-contained control unit with electrode, spark ignition safety pilot burner, control light and alarm bell. Safety controls are connected through conduit to solenoid valves on both the main gas line and pilot line. Additional protection is provided by a vacuum control switch located in the fan suction, insuring that proper exhaust conditions are provided before the gas may be admitted to the fire tubes. Operation of the burner equipment is automatically controlled by the temperature of the water bath by means of an adjustable temperature switch.

The exhaust fan provides for the withdrawal of a greater amount of air from the room in which the unit is located than that required for combustion. The auxiliary air inlet to the fan may be connected to ventilating ducts to provide forced draft ventilation for lower portions of the control chamber or of the heater rooms.

GAS OR OIL FIRING

The unit may be easily adapted for oil firing for the initial heating of digesters before gas is available or at times when the gas supply is inadequate. Oil burning accessories can be supplied at extra cost or are available on a rental basis if required only for initial operation.

STANDARD SIZES

The P.F.T. Combined Heater and Heat Exchanger is available in five standard sizes as follows:

Size No.	0	1	2	3	4
Normal output rating at 80° thermal efficiency in B.t.u. per hour	100,000	250,000	500,000	750,000	1,000,000

Units are conservatively designed in regard to heat transfer of the sludge tubes and fire tubes and may be operated at a 50 per cent overload with but a slight drop in thermal efficiency. Units have been operated at 185 per cent of normal output ratings during test periods.

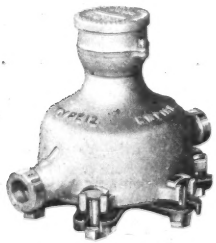
The units are so designed that they can be installed in groups to make up any combination of heat requirements necessary in a digestion system. For instance, any number of the larger size units can be installed side by side with manifold connections so that any or all of the units can operate in parallel to provide necessary heat control for the digestion system, with the number of units in operation dependent upon the season of the year and heat requirements.

PITTSBURGH EQUITABLE METER COMPANY

Pittsburgh, Pennsylvania

PITTSBURGH-EMPIRE WATER METERS

Pittsburgh-Empire Water Meters have for years been used by large and small municipalities alike throughout the country. Their excellent construction, maintained accuracy, and long life have been thoroughly proven on hundreds of thousands of installations. In sewage disposal plants they are recommended for measuring the heated water circulated through digestion tanks, and all cold water piped for various uses throughout the plant.



Empire Water Meter.

Pittsburgh Tropic Hot Water Meter.

Hot water meters are of a special construction to operate under high temperatures.

EMCO METERS FOR SEWAGE GAS

It has become common practice in the design and operation of sewage disposal plants to utilize the gas generated during sludge digestion as a source of heat and power. Since modern engineering methods have demonstrated that accurate measurement is a necessary part of the control of any process, the metering of this gas is an important matter and the choice of meter, one that should be given careful consideration.

Emco Sludge Gas Meter.

Experience has proven that the conventional meter used for measuring manufactured and natural gas will not operate satisfactorily on this type of service due to the destructive effect which sewage gas has on materials commonly employed in the construction of gas meters. For this reason Emco meters for sewage gas are especially constructed from materials which laboratory tests have proven resistant to the action of this gas. The outer case is of heavy cast iron with interior coated with a special preparation. The working parts are made from stainless steel, lead nickel silver, tinned brass, or illium, depending on the operation each has to perform, while a special tannage and treatment is given to the diaphragms.

Specifications of Emco Meters for Sewage Gas

Meter No.	Size of Conns., Inches	Length, Inches	Width, Inches	Height, Inches	Weight, Pounds	Capacities, Cu. Ft. per hour of 0.6 Specific Gravity Gas	
						½-inch Pressure Absorption	2-inch Pressure Absorption
0	$\frac{3}{4}$, 1 or $1\frac{1}{4}$	$9\frac{7}{16}$	$8\frac{3}{4}$	$11\frac{3}{8}$	38	175	350
1	1, $1\frac{1}{4}$ or $1\frac{1}{2}$	$11\frac{1}{8}$	$9\frac{1}{8}$	$14\frac{1}{4}$	46	275	550
2	$1\frac{1}{4}$ or $1\frac{1}{2}$	$12\frac{3}{4}$	$10\frac{1}{8}$	$16\frac{5}{8}$	67	350	700
$2\frac{1}{2}$	2	$20\frac{3}{8}$	14	$25\frac{1}{8}$	227	850	1800
3	2 or 3	$22\frac{1}{2}$	$16\frac{1}{2}$	$27\frac{13}{16}$	305	1200	2500
4	3 or 4	$27\frac{1}{4}$	$19\frac{3}{4}$	$32\frac{7}{8}$	506	1700	3800
5	4	40	$20\frac{3}{4}$	$51\frac{1}{8}$	1000	5000	10000

* Note: Capacity ratings of gas meters are usually based on a gas of 0.6 specific gravity. To correct for gas having a higher or lower gravity, the following formula should be used:

$$R_g = R\frac{\sqrt{0.6}}{\sqrt{G}}$$ where: R_g = rating for gas having specific gravity G
G = specific gravity of gas
R = rating in table above

ROOTS-CONNERSVILLE BLOWER CORP.

509 Wellman Avenue, Connersville, Ind.

GREATER FLEXIBILITY IN AIR SUPPLY WITH THE "R-C" MULTI-CAPACITY DUAL IMPELLER BLOWER

An adequate air supply is just as important to the efficient operation of the activated sludge type sewage treatment plant as it is to the health of an individual. The air requirements for most activated sludge plants vary widely during the daily period of operation, as well as from week to week and season to season. Just as an individual automatically breathes faster and deeper for more oxygen to take care of increased exertion, so, too, must the air supply for activated sludge be flexible enough to supply adequate air for any period of increased rate of sewage flow.

The Roots-Connersville Multi-Capacity Blower (operating on the rotary positive displacement principle) is one of the most effective means of obtaining an air supply sufficiently flexible and adequate to meet varying requirements.

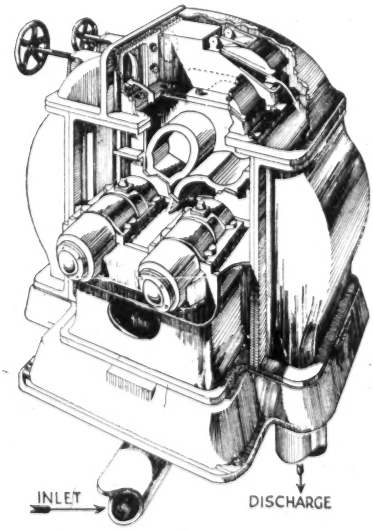


FIG. 1.—Cut-away view of the Roots-Connersville Multi-Capacity Dual Impeller Blower.

The blower chamber of this unit (see Figure 1) is divided into two sections of different widths, with the widths of the two sets of impellers of corresponding size. The size of these two blower sections can be made to suit any desired capacity ratio—such as 30 per cent and 70 per cent. Each section represents a separate blower, but by assembling both sets of impellers in one case and carrying them on the same shafts and bearings, utmost economy, compactness, convenience of operation, and flexibility of air supply are achieved. In effect, there are obtained the capacity advantages of *three* separate and different size blowers, with the economy advantages of a compact *one-unit* installation, driven by one constant speed motor. Practically full power saving is given in this arrangement at the two lower capacities.

When the two by-pass valves are closed, the total capacity of both sections is delivered into the line. With either one of the valves open, that section is by-passed without compression. This by-passing takes negligible power—only 1 per cent to 2 per cent of the total. Figure 2 shows an installation of multi-capacity blowers.

DOWN-RUN PIPE

In large units of either dual impeller or regular construction, where air piping is to be kept below the floor, both inlet and outlet connections can be made to blower bedplate, generally through rubber expansion joints (see Figure 3). In this arrangement, pres-

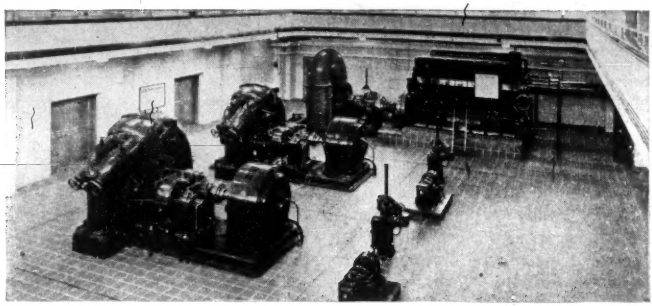


FIG. 2.—Three Roots-Connersville Blowers at the Ft. Wayne, Ind., plant. The two nearest are motor-driven Multi-Capacity type of 2,800/4,200/7,000 c.f.m. each at 7¾ lbs. pressure. The third blower in background is a standard type "R-C" Blower of 11,000 c.f.m. capacity, driven by a sewage gas engine.

sure relief valve and no-load starting by-pass valves are generally built in the bedplate.

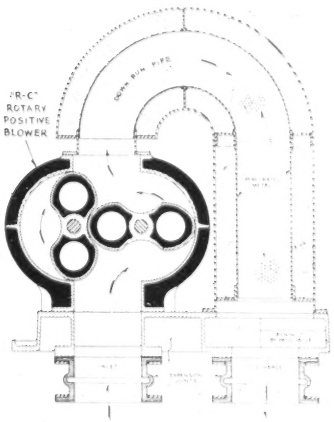


FIG. 3.—Cross-section through standard "R-C" Rotary Positive Displacement Blower and down-run pipe.

THE POSITIVE DISPLACEMENT PRINCIPLE

Twin impellers (one set on the standard blower and two sets on the multi-capacity blower) alternately suck in, momentarily entrap, and then expel definitely measured amounts of air. The impellers need no seal or lubrication. Pressure automatically builds up to overcome resistance on the discharge side. Note in Figure 3 the extremely simple construction of the Roots-Connersville Rotary Positive Blower. There are no restricted passageways, springs, or small wearing parts to require adjustment or replacement. There is no metal-to-metal contact between the impellers, or impellers and casing. Their contour and finish is such that a clearance of a few thousandths of an inch is precisely maintained by a pair of accurately cut timing gears which operate in a bath of oil. The only parts subject to wear are the bearings and gears which are all oversize, and thoroughly lubricated.

ROYER FOUNDRY AND MACHINE CO.
158 Pringle St., Kingston, Pa.

MORE SLUDGE FERTILIZER GOES INTO THE NATION'S FOOD OUTPUT

1945 revealed not only still more mouths for America to feed in various parts of the globe, but also a serious food situation here at home—too familiar to require further discussion.

The year was marked, however, by a

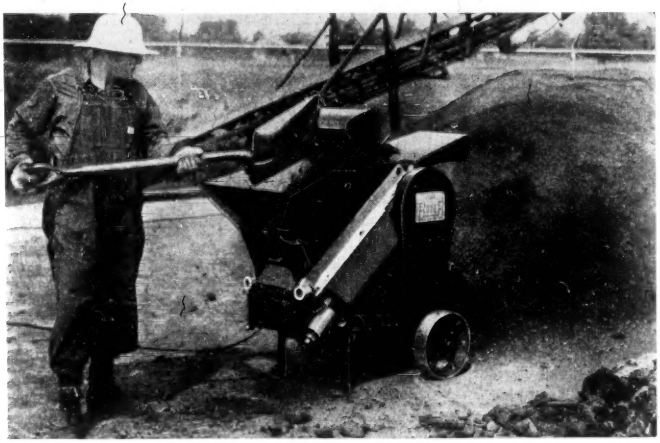


FIG. 1.—Royer Sludge Disintegrator, Model NSC-2, at the Kenosha, Wisconsin, sewage treatment plant.

substantial increase in the use of sludge fertilizer, and in the number of sewage disposal plants which are helping to increase the nation's food production by converting their sludge into fertilizer instead of burying or incinerating it.

Many sewage plant officials obtained a broader understanding of the fertilizing value of sewage sludge from the article on that subject by A. H. Niles of Toledo, Ohio, which appeared in SEWAGE WORKS JOURNAL a year ago. This article brought out some significant facts, previously not generally known. Sewage sludge, in addition to nitrogen, phosphorous and potash, contains other soil-enriching mineral elements, and embodies valuable physical properties not found in chemical fertilizers.

Mr. Niles also pointed out that sewage sludge retains its fertilizing value over an appreciable period, which is very important during a long growing season, and that its fertilizing elements are not readily leached out, as is the case with chemical salts under heavy rains. Likewise, that sewage sludge contains enormous numbers of nitrogen fixation bacteria, which have the power to transform the nitrogen in the air into useful compounds which can be assimilated by plants for food, and also break down organic matter in the soil into a useful state for stimulating plant growth.

These, and other fertilizing values, are present in sewage sludge, which, as it comes from the drying beds, is not in condition for use as a fertilizer. Growers have neither the time or facilities for processing sludge cake to usable form. This is now being accomplished, at a steadily growing number of sewage treatment plants, by means of the Royer Sludge Disintegrator.

The labor involved is less than that required to bury or burn the sludge, and these profitless operations are eliminated. The only work required is to shovel the sludge cake into the hopper of this rugged, inexpensive machine, which is available in portable and stationary models, and in sizes to meet the needs of cities large and small. Figure 1 shows a Royer at work.

The machine uses an endless belt of tough, resilient material upon which are mounted rows of steel teeth or sprigs to accomplish the thorough shredding, mixing and aerating of the sludge cake. This belt travels upward at an angle of 45°, and the teeth are so shaped and the rows so closely spaced that caked, lumpy or matted material is combed or raked until it is reduced to pea-sized particles. Sticks, stones and trash gravitate to the bottom of the belt, where a gate permits periodical removal.

The Royer discharges onto pile or truck a ready-to-use and effective fertilizer. If desired, chemicals can be mixed in during the disintegrating process to make a high strength fertilizer. Sewage plants find a ready market for Royer-prepared fertilizer, and many of them have acquired a substantial source of income through a small investment.

Recent Royer installations include 119 machines at military establishments, where the sludge fertilizer is used for various purposes, including maintaining the growth of grass on airfields.

Official recognition of the value of sludge fertilizer has been given in the form of easing priority restrictions on the Royer, which is now available to all sewage treatment plants.

"Sewage Sludge Utilization Datalog," a comprehensive book on that subject, will be mailed on request by the Royer Foundry and Machine Co., Kingston, Pa.

SIMPLEX VALVE AND METER COMPANY

6725 Upland St., Philadelphia 42, Pa.

SIMPLEX AIR RELEASE VALVE

The Simplex Air Release Valve automatically vents air obstructions that might otherwise cause loss of operating efficiency or damage to pipe lines and pumps. Simple, rugged construction assures dependable service. One lever movement operates a tightseating needle valve, actuated by a heavy glass ball float. Types available for pressures up to 1,250 lbs. per sq. in.—tested to several times the service working pressure.

Type "B" Sewage Air Release Valves are especially designed to meet the particular conditions of sewage service and eliminate shutdowns caused by trapped air and gases from decomposing organic matter. A permanent hose connection makes it possible to accomplish routine periodic backflushing merely by opening the water valve to allow clear water to fill the release valve and the system. The flush is quickly and easily completed without dismantling any part of the installation.

SIMPLEX AIR INLET VALVE

Eliminates the possibility of collapse of pipe line walls due to sudden drop in pressure in gravity flow line. The non-collapsible float is buoyed by the water in the line until a condition arises which tends to create a vacuum—then the buoying effect of the water is lost, the float drops from its seat, to admit air and destroy the vacuum. The Air Inlet Valve serves another useful purpose in allowing escape of air from summits while filling lines after shutdown.

TYPE MO METER

Indicates, records and totalizes fluid flow rates. Consistent high accuracy over wide flow range (up to 43 to 1); extreme sensitivity to every change in flow; simplicity of design, trouble-free operation, minimum maintenance cost. Evenly graduated, direct reading flow scale and chart. Floor stand, wall bracket or Panel Board mounting.

AIR DIFFERENTIAL FLOW METER

For Liquids Containing Suspended Solids

Corrosive fluids are measured without directly touching this highly accurate instrument, since the differential head is measured directly from the primary device and then transmitted to the meter through the medium of air. Therefore, the meter is unaffected by the fluid being measured, and gives trouble-free service year in and year out. The Simplex Air Differential Meter may be placed at any elevation regardless of the pressure in the line. It may be installed to integrate, record and totalize in any combination; the chart is of the evenly spaced, direct reading type; flow measurement is easily read over the entire range of the meter.

TYPE MS FLOW RATE METER

Accurately indicates, records and totalizes flow rate. Bell-shaped float automatically extracts the square root of the law of flow and makes possible the direct reading chart—evenly graduated from 0 to maximum. The arm of the recording pen connects directly with the float for inevitable accuracy of transcription and sensitivity to flow change.

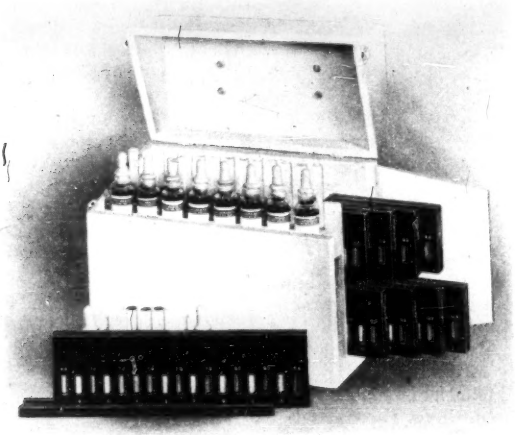
W. A. TAYLOR & CO.

York Road and Stevenson Lane, Baltimore 4, Md.

EFFECTIVE CONTROL OF pH IN SEWAGE

Digestion of sewage sludge in Imhoff, septic, or separate digestion tanks proceeds best at pH values near the neutral point or slightly above (pH 6.8–7.6). When the pH varies from the optimum, digestion will be slow and offensive odors and foaming may occur. Proper pH is secured by maintaining the proper ratio of ripe sludge to fresh solids or, if necessary, by adding lime.

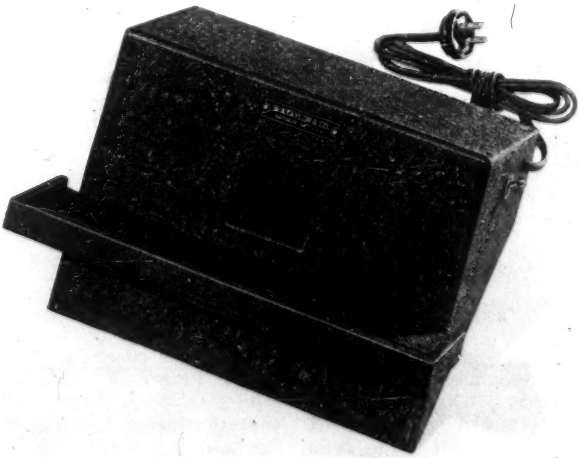
Activation of sludge seems to pro-



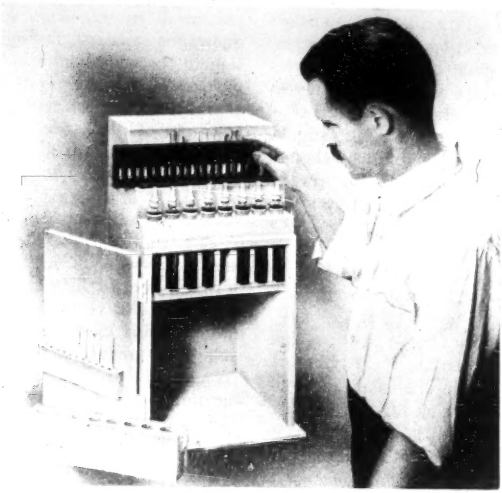
Taylor Long Range Slide Comparator.

ceed best when the sludge is slightly alkaline. Filtration of activated sludge is most efficient at an optimum pH which depends on the coagulating chemical being used. At first observation, one would expect it to be a difficult matter to determine the pH of sewage sludge by a colorimetric method. While a direct test is not feasible, fortunately sewage sludge is so highly buffered that it can be diluted considerably with distilled water without any appreciable change in pH.

Buffer action is the property pos-

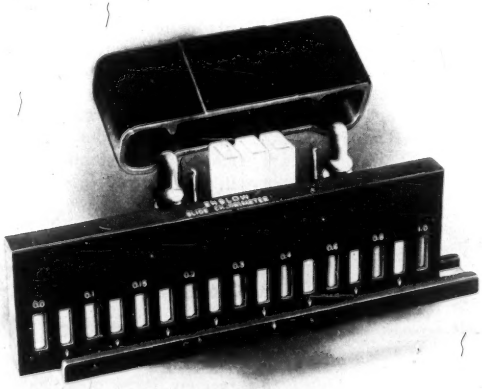


Taylor Midget Dalite Lamp.



Taylor Dalite Slide Comparator.

sessed by some materials to resist change in pH. This is due to the presence of weak acids or weak bases and their salts. The stability of any buffer system will depend on total concentration and the ratio of salt to weak acid or base. Reasonable changes in concentration will not materially change the pH of such a mixture as long as the ratio remains the same. This is an advantage since colorimetric pH measurements can be made on such materials, even when highly colored or turbid, by diluting with distilled water.



Taylor-Enslow Slide Chlorimeter.

The degree of dilution possible depends on the concentration and the particular buffer system, but the safest procedure is to dilute only as far as necessary to make satisfactory readings.

Samples to be used for test should not be filtered since the pH may change during filtration. Samples of sewage sludge have been known to change as much as 0.5 pH over a period of two hours necessary for filtration of the gelatinous material. Filtering under reduced pressure may cause greater errors due to the loss of carbon dioxide.

The small (11.5 mm.) test tubes and color standards used in the Taylor pH Comparator enable one to make accurate determinations on far more highly colored and turbid solutions than is possible with other outfits using larger tubes and standards. This makes it possible to keep dilutions at a minimum in testing sewage sludges. Dilution of 1 part of sludge with 19 parts of water is the usual recommendation. Some sludges, however, may not require this much dilution, while others may require slightly more.

For sewage work the Taylor Long Range pH Slide Comparator is recommended. This is a portable outfit containing all equipment required for making pH tests. While it can be obtained with any 3 to 9 color standard slides within the range pH 0.2 to 13.6, the Model T-3 with chlorphenol red (pH 5.2–6.8), bromthymol blue (pH. 6.0–7.6), and phenol red (pH 6.8–8.4) is usually sufficient for sewage control. All color standards are enclosed in plastic slides and carry an unlimited guarantee against fading. In addition to the slides the outfit contains a molded plastic comparator base, vials of indicator solution with pipettes, and a supply of 5 ml. test tubes, all in a wooden carrying case.

If it is necessary to make pH tests at night or in a dark place, the Taylor Midget Dalite Lamp can be used, or a Taylor Dalite pH Slide Comparator can be secured.

In addition to disinfection of sewage plant effluents, chlorine and hypochlorite are being used to control slime, as well as to reduce B.O.D. and odors. To maintain proper residuals some accurate method of testing must be used. This is provided in the Taylor-Enslow Slide Chlorimeter, which consists of two principal parts, a base and a slide, both molded from plastic. The base contains 3 clear plastic (Lucite) cells, 2 vials of ortho-tolidine solution, and two 0.5 ml. pipettes. Two chlorine slides are available: one containing the standards, 0.0, 0.1, 0.15, 0.2, 0.3, 0.4, 0.6, 0.8, and 1.0, and the other the standards 0.0, 0.1, 0.2, 0.4, 0.6, 0.8, 1.0, 2.0, and 3.0. All standards are in p.p.m. free (or residual) chlorine.

When the ortho-tolidine method is used to test for residual chlorine, the pH of the test portion and the ratio of ortho-tolidine to chlorine must be controlled. The procedure employed with the Taylor-Enslow Slide Chlorimeter automatically regulates these conditions so as to give accurate results. In addition all standards carry an unlimited guarantee against fading.

TENNESSEE CORPORATION

Atlanta, Georgia

FERRI-FLOC IN SEWAGE TREATMENT

"Ferri-Floc," commercial ferric sulfate, finds numerous applications in sewage and industrial waste treatment. These uses have increased considerably over the past few years due to the extremely large quantities of industrial wastes from many of the various war plants, which must be treated, as well

as to the addition of coagulation to many overloaded municipal sewage treatment plants.

One of the most interesting uses has been for sludge conditioning for vacuum filtration. One of the peculiarities of ferric sulfate in such a process is that it frequently can be used without lime. Several such plants in the United States are now using "Ferri-Floc" alone for their sludge conditioning, and the results have proven this treatment to be extremely economical and much more trouble-free than previous treatments using lime. The success of this treatment apparently depends largely upon the ammonia content of the sludge. The greater the ammonia content, the greater the quantity of "Ferri-Floc" required to produce proper coagulation of the sludge. Rapid mixing for a period of only five minutes is required. Longer mixing tends to break down the coagulated particles at a rapid rate.

In the event of elutriated sludge, from which the ammonia has been almost completely removed, "Ferri-Floc" should give good coagulation at a ratio of about two per cent by weight of dry solids. This treatment will not work at all on sludges containing relatively high ammonia as the buffering action of the ammonia itself prevents the rapid lowering of the pH. The pH of sludge so coagulated usually varies from 6.2 to 6.4.

It does seem that any plant faced with the problem of sludge filtration should consider the use of ferric sulfate as a sludge coagulant and should at least experiment in the laboratory to determine whether or not it would be possible to condition their sludge without the use of lime.

For the past several years municipal sewage treatment plants in many sections of the country have been so grossly overloaded as a result of increased population and added industrial loads that severe pollution of the receiving stream has resulted. Many such installations have installed chemical precipitation as an aid to their plants and have so found it possible to increase the apparent capacity of the plants by as much as 50 per cent without the addition of major structural improvements. Such sewages normally will vary greatly in pH through the

Standard dry feeder feeding "Ferri-Floc."

course of the day, and one of the prime requirements of satisfactory coagulants has been coagulation over a very wide pH range without major changes in the coagulant dosage. Ferric sulfate has proven to be the ideal coagulant for such installations as it will coagulate over a wide pH range without affecting the dosage; most other coagulants require constant pH correction.

Most of the cities which have resorted to this type of treatment have been so well satisfied with results that they contemplate improving their chemical precipitation facilities in the days following the war rather than making major structural changes to their existing plants. Such treatment has proven very inexpensive and dosages range from 20 parts per million to 60 parts per million depending upon the clarification required. In fact, experience has shown that it is possible to clarify the primary sewage to the point that the secondary treatment processes will not receive sufficient organic material and bacteria to function properly. Therefore, the degree of treatment afforded in the primary tanks depends entirely on requirements of the secondary units. Primarily, chemical precipitation should be employed to level out peak B.O.D. loadings.

Industrial waste problems have likewise become of increased complexity during this war period. Most of these industrial wastes are very low in organic content, or bacteria, and do not lend themselves readily to biological processes of sewage treatment. As a result of this, many of the industries have been forced to turn to chemical precipitation to effect anything like satisfactory treatment. Again, due to its ability to flocculate over a wide pH range, "Ferri-Floc" has come into wide use. It is now finding application in the oil fields, in refineries, in synthetic rubber production, powder plants, etc., and has lent itself to these widely differing wastes with a minimum of operating difficulty and equipment required.

"Ferri-Floc" can be rapidly put into solution without elaborate dissolving equipment. A number of standard model feeders are on the market today to handle properly this coagulant, or any standard dry feeder can be converted to handle "Ferri-Floc" by slight changes to the dissolving equipment which usualy cost less than $100 per feeder. In the dry state, the product is non-corrosive to metal and concrete and can be stored in bulk without difficulty, regardless of climatic conditions.

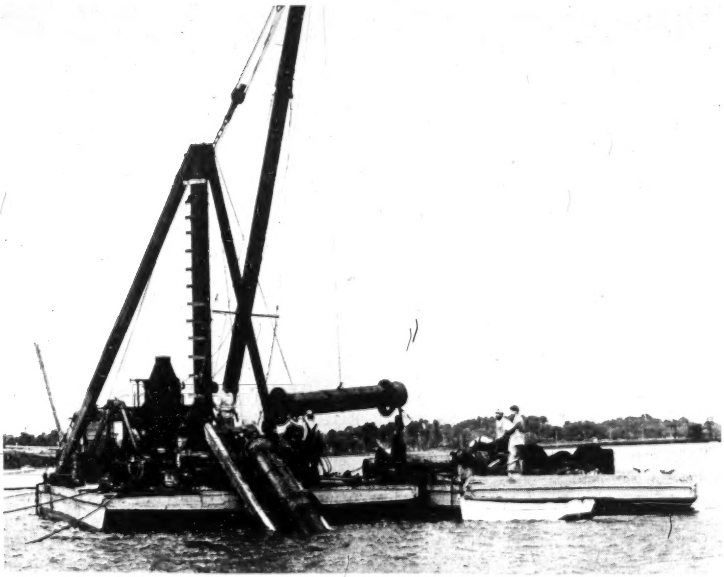
The Tennessee Corporation maintains a staff of technically trained field men with the sole object of giving the users and potential users of "Ferri-Floc" technical assistance in their water and sewage treatment problems. These men are available for your particular problems without any obligation whatsoever. We are proud of the record "Ferri-Floc" has made in the many large plants in which it is being used and invite you to write us for additional assistance, or information.

UNITED STATES PIPE AND FOUNDRY COMPANY

General Offices: Burlington, N. J.

CAST IRON PIPE FOR SEWERS

The use of cast iron pipe for sewers is steadily increasing throughout the country. Many new sewage treatment plants are being built, some in conjunction with a new sewer system, and others to augment an already existing system. Furthermore, major revisions are being made in large numbers of existing treatment plants, not only to increase their capacity but to provide



20-inch Usiflex Joint Pipe for sewer force main across river.

more complete treatment that will produce an effluent of better quality. Treatment costs money; the amount of money is almost directly proportional to the volume treated. Logically, therefore, every gallon of water that seeps into the mains through leaky joints, cracked pipe or from other sources not only crowds the sewer but costs good money to convey it through the various treatment stages.

Cast iron pipe possesses three outstanding properties that are most important for present day sewer construction:

1. Tight pressure type joints that prevent infiltration, thereby reducing treatment costs and incidentally eliminating trouble with tree roots.
2. Compressive strength to resist heavy earth loads due to deep fills over the pipe. Beam strength to withstand stresses caused by earth movement. Bursting strength to resist internal pressure when used as a force main or when pressure might temporarily occur due to floods.
3. Long life that has been proven by years of satisfactory service, consequently permitting a low annual amortization charge on the original investment.

There are many instances in various parts of the country where cast iron pipe has been installed in sewage disposal systems for flow mains, force mains, stream crossings, outfall sewers and in treatment plants.

Cast iron flow lines are generally installed where the pipe are laid in water saturated soil to eliminate troublesome and costly infiltration.

Cast iron force mains are being installed at a steadily increasing rate due to the growing demand for sewage

treatment. Treatment plants are usually located some distance away from the more densely populated sections of a community. Frequently, it is not possible to have gravity flow to the plant. In those cases the sewage flows into a sump and is then pumped through a force main to the treatment plant. Illustrated here is a cast iron flexible joint force main being laid on the bottom of a river.

Cast iron outfall sewers have been widely and satisfactorily used to convey sewage, in most cases treated and in some cases untreated, out into a body of water for final disposal.

Cast iron pipe and fittings are used extensively to transport the sewage through the various treatment stages. One of the illustrations shows these products installed in a recently completed sewage treatment plant.

THE VAPOR RECOVERY SYSTEMS COMPANY

2820 North Alameda Street, Compton, Calif.

CONSULTANTS, DESIGNERS, AND MANUFACTURERS OF GAS CONTROL AND TANK EQUIPMENT

Modern sewage treatment units incorporate operating gas control refinements comparable to the most highly specialized process plant installations in the world.

Keeping abreast of the rigid requirements of modern sewage treatment practice, VAREC designers and engineers have a definite conception of the utilization of its sewage works equipment. With many years experience in gas control and safety equipment The Vapor Recovery Systems Company has developed a line of gas control safety devices for sewage treatment plants that embody the latest engineering designs in this field.

In the multiple digester gas system, the VAREC approved pressure relief and vacuum breaker valve with flame arrester is installed on the digesters and gas storage tanks to maintain system operating pressure and to protect the units in case of fire from without. Being constructed of aluminum throughout, they are noncorrosive, easily inspected and maintained.

VAREC approved flame traps are installed throughout wherever there is a possibility of fire inside the plant piping. These units are made of corrosion resisting aluminum and afford a positive flame stop. All VAREC flame arresters are approved by the Underwriters' Laboratories.

To maintain system pressure at the

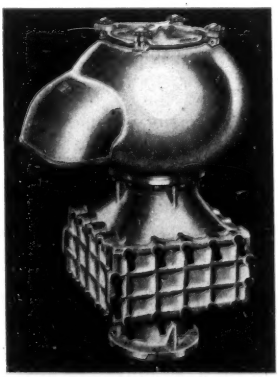


FIG. 1.—VAREC approved pressure relief and vacuum valve with flame arrester.

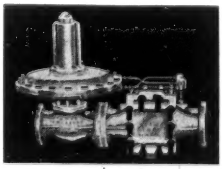
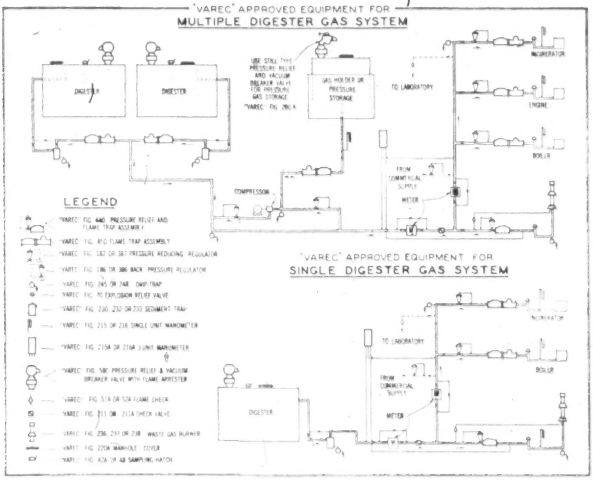


FIG. 2.—VAREC approved pressure relief and flame trap assembly.



waste gas burner, a VAREC pressure relief and flame trap assembly is installed. This unit consists of a sensitive diaphragm-operated regulating valve in conjunction with a VAREC flame arrester, into which a thermally operated bypass valve is built. In case of fire in the system, this bypass valve automatically closes the regulating valve, providing a positive flame check.

VAREC approved waste gas burners are manufactured with a wide capacity range and are furnished with or without pedestal mounting, as required. The pilot valve gas line is protected by the installation of a VAREC approved flame check.

To handle sudden surges in pressure due to explosions or momentary plant fluctuations, a VAREC approved explosion relief valve is installed in the system. Being dead weight loaded, it insures a positive and foolproof relief valve.

In plants where the gas is used to operate boilers, engines or other equipment, a VAREC approved pressure regulating valve is installed in the gas line to each piece of equipment. These valves are set to operate at a lower pressure than the VAREC pressure relief and flame trap unit, thus making sure that all the gas required is available for useful work before any is allowed to go to the waste gas burner.

VAREC approved manometers are used through the plant for indicating system pressure. They are obtainable in single or triple reading units with or without push button control. This latter feature is a built-in push button type valve that keeps the manometer shut off until the button is pushed. It is another VAREC engineered feature incorporating safety devices, for should the manometer glass break, no dangerous gas is allowed to escape from the system.

One of the basic design fundamentals in gas plant engineering is to keep the lines drained and free from moisture. A full line of VAREC approved sediment traps and condensate drip traps is available to meet this requirement.

The VAREC approved check valve is required in a system operating at low pressure. Designed for this purpose, its aluminum clapper reduces the pressure required to keep it open.

VAREC non-sparking and gas tight manhole covers, installed on all tanks, provide a quick entry into the tank.

VAREC gauge and sampling hatches are also gas tight and non-sparking and have a foot pedal design to facilitate sampling and gauging.

All VAREC regulating and control equipment is flow tested in the most modern type laboratory. Curves are published for each piece of equipment and can be used to determine the most economical size for each specific installation.

Due to government restrictions on critical material, The Vapor Recovery Systems Company has developed a new pressure relief and vacuum breaker valve. These valves incorporate the standard features of the regular relief valves plus many engineering features developed especially to meet wartime needs, viz.: hyperbolic, static-balanced pallets insure less "blow-down"; pallet guides are not exposed to corrosive tank vapor; expanding streamlined passageways eliminate directional changes and eddying currents; wind drift is eliminated by scientific design; materials are used having best thermal, electrical potential, and non-corrosive factors in combination; replaceable seats guarantee minimum maintenance expense.

All VAREC equipment is pretested to actual field installation; the pallet guiding system positively prevents binding for freezing, drainage throughout the unit is complete—no condensate can accumulate.

Twenty years experience is built into every unit.

WAILES DOVE-HERMISTON CORPORATION

Westfield, New Jersey

RECENT EXPERIENCE IN SEWAGE PLANT CORROSION PREVENTION

A problem that the sewage works engineer—or any maintenance engineer—has found difficult to solve is that of corrosion prevention—especially on surfaces exposed to sewage. Protective coatings selected for important sewage works applications should be based on performance records established by them as these offer an excellent guide to an economical and reasonable safeguard against corrosion and deterioration.

A material long used in sewage plants for corrosion protection is a coal tar base product called Bitumastic No. 50, manufactured by the Wailes Dove-Hermiston Corporation. When it was first developed, sewage works engineers were among the first to specify it to protect buildings and equipment from the ravages of moisture, fumes and sewage. Of interest is the following report on a round table discussion of painting of treatment plants that appeared in a recent issue of a leading national magazine devoted to sewage works. We quote directly from Mr. William D. Denise, Superintendent of the sewage treatment plant at Greece, N. Y. Mr. Denise states in part:

"After using numerous makes and types of paints both on a plant scale and on sample applications, we are now using a tar base product made by the Wailes Dove-Hermiston Corporation. For all underwater applications and where conditions are most severe, such as channel cover supports, ferric chloride tanks, and sludge mixing tanks, Bitumastic No. 50 is used. For above water applications where weather is the only factor, such as railings, motors, floodlight poles and channel covers, Bitumastic Black Solution is giving very satisfactory results.

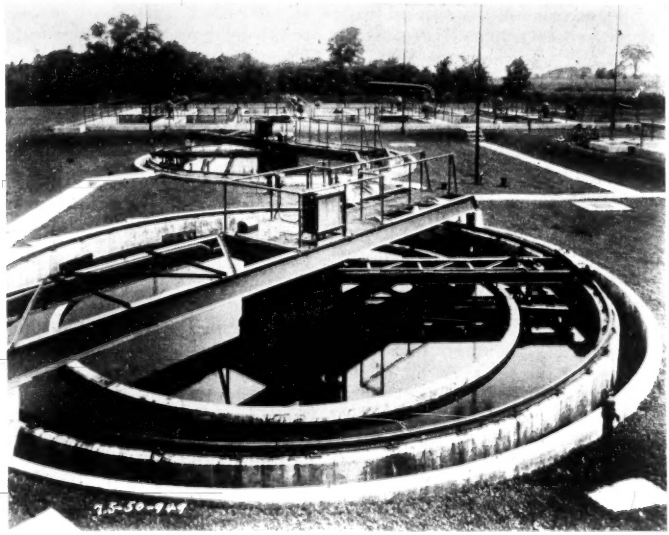


FIG. 1.—Clarifier and magnetite filter equipment protected by Bitumastic No. 50 below water and by Bitumastic Black Solution above water.

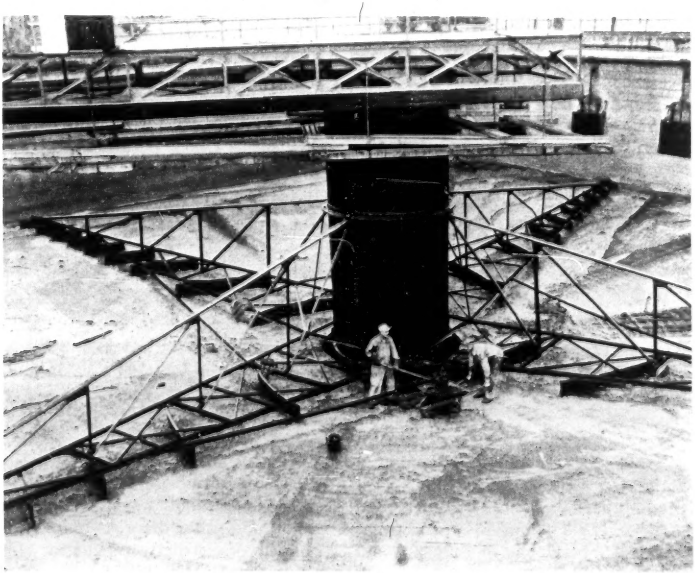


FIG. 2.—One of eight clarifiers coated with Bitumastic 70–B Enamel at Ward's Island plant, New York City. Control gates in background protected similarly.

The sludge incinerator is coated with Wailes Dove-Hermiston's Hi-Heat Gray and has held up where the heat has been the most intense.

"It is our experience that tar base paints are superior to all other types that we have tried, and have given excellent service. It is necessary to paint the iron work every year but the other surfaces will require coating about every three years."

Bitumastic products have established themselves in the field on the basis of comparative tests such as this in treatment plants throughout the country. It was natural, therefore, that they were specified for the most ambitious sewage treatment project in the history of sewage engineering, described below.

The Ward's Island Sewage Plant of New York City, completed in 1937 at a cost of approximately $30,000,000, clarifies and purifies 190 million gallons of sewage a day by what is conceded to be the most advanced form of treatment known. Bitumastic products were used extensively in protecting this huge plant from the ravages of corrosion. This plant drains areas in Manhattan and the Bronx of 10,592 acres with a population of nearly 2,000,000 people. Six pumping units, each 90 m.g.d., lift the sewage 46 feet to the eight preliminary settling tanks. From the preliminary settling tanks the flow is to a series of aeration tanks from which the sewage passes to 32 final settling tanks. The sludge is discharged into sludge storage tanks from whence it is taken by sludge vessels and disposed of at sea. The 54-inch aeration piping inside the blower building was coated inside and outside with Bitumastic Black Solution. The same coating was used to protect the steel air main extending from the building line to the aeration tanks.

Hot-applied Bitumastic Enamel was applied to the interior of the four sludge storage tanks and the two cylindrical grease tanks. Overhead and interior walls, partitions and bottoms, and all piping and miscellaneous steel work of the tanks in the sludge vessels were coated with hot Bitumastic 70 B Enamel. Bitumastic Enamel was also applied to the inside of the hulls of the ships, floor frames, keels, engine foundations and miscellaneous steel work in the bottom of the steering compartment and other areas subject to severe corrosion. The bracing above the level of the floor frames and the underside of the sludge deck were protected with Bitumastic Black Solution.

WALLACE AND TIERNAN CO., INC.

Newark 1, New Jersey

DISINFECTION OF SEWAGE

The need for sewage disinfection cannot today be overlooked. With increasing population the growing demands on water supplies necessitate using sources of supply hitherto considered unsuitable. The increasing popularity of swimming has led to the use of the most available bathing beaches, lakes and watercourses. The national resentment against the pollution of streams and rivers is gaining momentum. All of these have centered the attention of sanitarians on sewage treatment. As a final measure of securing complete health protection, sewage disinfection, with chlorine, is accepted practice.

ODOR CONTROL

The control of obnoxious odors from sewage treatment works, long outfall sewers and other disposal plant appurtenances is distinctly a field for chlorination. Neutralization of hydrogen sul-

fide (the gas responsible for these obnoxious odors), or prevention of its formation by controlled application of chlorine, is not only quite practicable but also satisfactory in results and economy of operation.

B.O.D. REDUCTION

Treatment plants discharging effluents into watercourses having extreme seasonal variation in flow have profited from controlled chlorination to reduce biochemical oxygen demand. Field tests have often shown a reduction in the 5-day B.O.D. of more than 30 per cent.

OTHER ADVANTAGES

Similarly, chlorine prevents filter "ponding." The filters are unloaded of their organic accumulations. Surface algae growths are killed and washed out.

TECHNICAL INFORMATION

Wallace & Tiernan representatives will gladly discuss any specific sewage chlorination problem. Technical bulletins on the many phases of sewage chlorination and W & T Chlorinators will be sent free on request. Address Wallace & Tiernan Company, Inc., Newark 1, N. J.

YEOMANS BROTHERS COMPANY

1433 N. Dayton St., Chicago 22, Ill.

CENTRIFUGAL PUMPS, PNEUMATIC EJECTORS, ROTARY AIR COMPRESSORS, SEWAGE TREATMENT EQUIPMENT

The past year has brought Yeomans appreciably nearer to its goal of Yeomans engineered equipment for all steps in the sewage treatment process from the pump house to the digester. Added was the new "Streamline" sludge collector for rectangular settling tanks and a complete and tested line of mechanically cleaned bar screens. In addition, other equipment announced previously saw installation and testing—with satisfactory results.

YEOMANS "STREAMLINE" SLUDGE COLLECTORS

Several new and outstanding features are presented with the "Streamline" sludge collector, which are designed to eliminate troublesome and annoying maintenance and operating chores. They include an automatic overload release with an alarm, special long-wearing cast flight shoes and individual gear drives for each tank.

The overload release, furnished when specified, provides instant automatic release when an overload occurs. The release is effected by an instantaneous break in the current through the motor starter and eliminates the conventional practice of using shear pins.

Also supplied are individual drives for each tank mechanism. This means that at no time will all tanks be out of service. Flights, flight chains, sprockets, attachments, bearings and drives are all of the finest quality, selected with a liberal safety factor and with emphasis on long life. Either automatic or manual scum removal devices can be furnished with this new sludge collector.

YEOMANS MECHANICALLY-CLEANED BAR SCREENS

Angle and vertical type screens as well as tailor-made units to fit unusual requirements are now being offered by Yeomans. Operation of these Yeomans screens can be either automatic or manual with open, semi-enclosed or fully-enclosed varieties available.

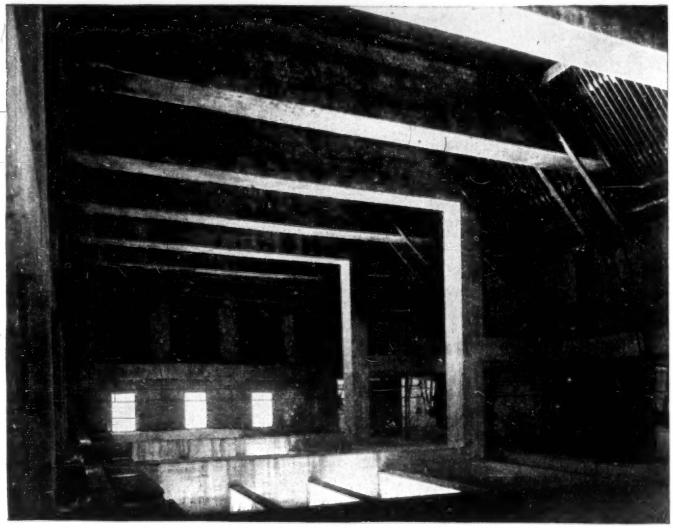


FIG. 1.—Yeomans Bros. Co. mechanically cleaned bar screens.

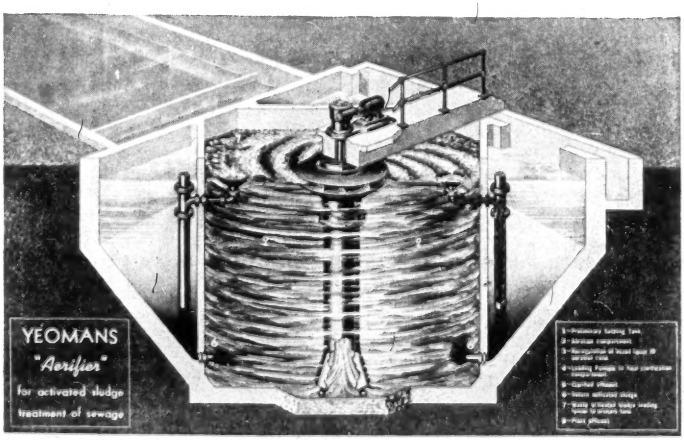


FIG. 2.—The Yeomans "Aeriffer."

An outstanding feature of the Yeomans mechanically-cleaned bar screen (Figure 1) is the arrangement of the spring-steel cleaning fingers in relation to the fixed bars of the bar rack. Each fixed bar at the bottom is offset, permitting the fingers of the rake head to enter the fixed-bar aperatures and make sliding contact with each bar. It is this action which thoroughly cleans the bar screens.

The rake head is held fixed and rigid throughout the full upward travel and then automatically discharges at the point of disposal from the screen. On the downward travel the rake head is again locked in the cleaning position. It cannot tilt or climb over screenings. The action is positive and foolproof, and minimum head loss is maintained whether on intermittent or continuous operation.

YEOMANS "AERIFIER"

Unusually good purification results are being secured by the latest Yeomans "Aerifier" packaged activated sludge treatment plant (Figure 2) which was placed in operation late in March at the Gulf Shores housing project near Panama City, on Florida's north Gulf Coast.

With half the dwellings occupied, tests made at the time the plant was approved by the Florida State Board of Health, showed that removals of 97 per cent in 5-day B.O.D. and 98 per cent in suspended solids were being accomplished. These percentages are based on the average of weekly determinations for the initial 30 days of operation and exceed the Yeomans guarantee.

This Gulf Shores plant is another all-Yeomans equipped unit—from the pumps in the lift station to equipment for final clarification. Included are centrifugal sewage pumps, a primary sludge pump, a "Streamline" sludge collector for the primary settling tank, and the mechanical aerator.

Heart of the plant is the "Aerifier" which combines aeration and final settling in one concrete tank. Essentially it is composed of a Yeomans "Spiralflo" aerator, adjustable loading funnels, angular corner clarifier compartments, an automatic return for activated sludge to the aeration tank, and an automatic return of excess activated sludge to the primary tank.

YEOMANS "RIM-DRIVE" CLARIFIERS

Installations of the "Rim-Drive" Clarifier mechanisms have been made and their operation successful. With all elements of the motor and drive mechanism mounted on the rim of the tank, this new, modern and simplified machine secures noteworthy saving in torque demand. Attractive plant design is greatly enhanced with the "Rim-Drive" as no unsightly bridges or railings are used.